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Outline of Proposed Constitutional Structure of the Society

By ROBERT E. DOHERTY
President, Carnegie Institute of Technology

Earlier articles in this series have outlined the background of the proposals to revise the constitution, and the organization problems of the Division of Administrative Officers of Engineering Colleges and of the Engineering College Research Association. This installment indicates the proposed constitutional structure.

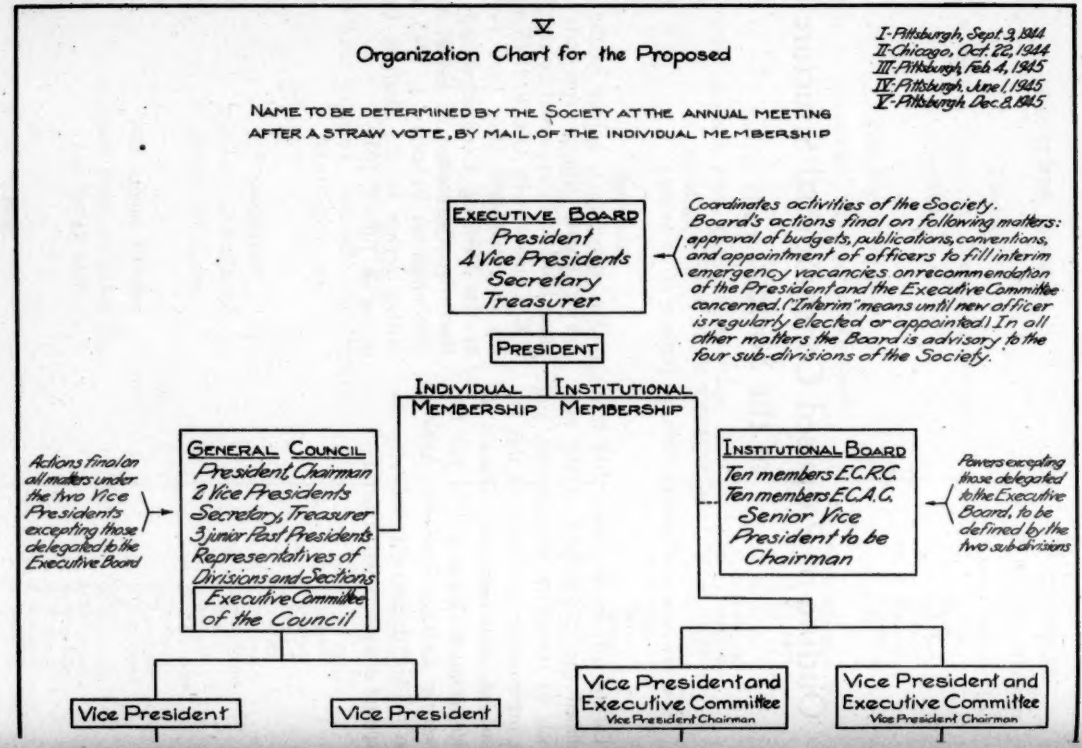
The structure is shown in the following chart, which represents the basic framework approved by the S.P.E.E. Council at its Dec. 8, 1945 meeting in Pittsburgh, after joint review by the Drafting Committee and the Executive Committee of E.C.R.A. in Pittsburgh on February 4, 1945, and further review by the Drafting Committee on June 1, 1945.

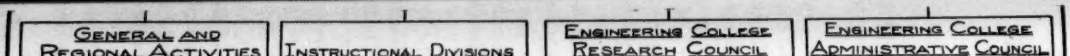
V

Organization Chart for the Proposed

I-Pittsburgh, Sept. 3, 1944
II-Chicago, Oct. 22, 1944
III-Pittsburgh, Feb. 4, 1945
IV-Pittsburgh, June 1, 1945
V-Pittsburgh, Dec. 8, 1945

NAME TO BE DETERMINED BY THE SOCIETY AT THE ANNUAL MEETING AFTER A STRAW VOTE, BY MAIL, OF THE INDIVIDUAL MEMBERSHIP


EXECUTIVE BOARD
President
4 Vice Presidents
Secretary
Treasurer
Coordinates activities of the Society. Board's actions final on following matters: approval of budgets, publications, conventions, and appointment of officers to fill interim emergency vacancies on recommendation of the President and the Executive Committee concerned. ("Interim" means until new officer is regularly elected or appointed.) In all other matters the Board is advisory to the four sub-divisions of the Society.
PRESIDENT
INDIVIDUAL MEMBERSHIP
INSTITUTIONAL MEMBERSHIP
Actions final on all matters under the two Vice Presidents excepting those delegated to the Executive Board
GENERAL COUNCIL
President, Chairman
2 Vice Presidents
Secretary, Treasurer
3 junior Past Presidents
Representatives of Divisions and Sections
Executive Committee of the Council
INSTITUTIONAL BOARD
Ten members E.C.R.C.
Ten members E.C.A.C.
Senior Vice President to be Chairman
Powers excepting those delegated to the Executive Board, to be defined by the two sub-divisions
Vice President
Vice President
Vice President and Executive Committee
Vice President Chairman
Vice President and Executive Committee
Vice President Chairman



Vice President | Vice President | Executive Committee, Vice President Chairman | Executive Committee, Vice President Chairman

General and Regional Activities	Instructional Divisions	Engineering College Research Council	Engineering College Administrative Council
Membership and activities correspond to those in present Sections and Branches and in other groups exclusive of Instructional Divisions	Membership and activities correspond to those in present Instructional Divisions - ie. English, Mathematics, Engineering Drawing, etc.	Membership and activities correspond to those in present Engineering College Research Association.	Membership and activities correspond to those in present Division of Administrative Officers.

NOTES

1. **Budget:**
   a. Executive Board's action to be based on recommendations from the several Vice Presidents and the Secretary.
   b. Budget distribution in first year to be approximately the same as in previous year. The E.C.R.C. budget will be based, in first year only, on $35 for each "full" and "Associate" institutional member.
2. **Dues:**
   a. Individual ($5).
   b. Institutional. Regular ($50), Associate ($25).
3. **Officers:**
   a. President. Elected annually by individual membership.
   b. Vice Presidents. Elected for 2-year terms, eligible for 2 terms.
      (1) Vice Presidents associated with General Council elected, in alternate years, by individual membership.
      (2) Vice Presidents associated with Institutional Council elected, in alternate years, by respective bodies concerned.
   c. Treasurer. Elected annually by individual membership.
   d. Secretary. Appointed by a committee consisting of the President and the 4 Vice Presidents.
4. **Committees:**
   a. Executive Committees to be constituted by the group concerned. The President and Secretary to be ex officio, full members of the Executive Committee of the General Council; and ex officio advisory members, without vote, of the Institutional Executive Committees.
   b. Committees, excepting Executive Committee, reporting to the Executive Board and to the General Council to be authorized by those respective bodies and appointed by the President.
   c. Committees reporting to the Institutional Councils to be authorized by the Executive Committee concerned and appointed by the corresponding Vice President.
   d. Committees of Sections, Branches or Divisions to be authorized by the body concerned and appointed by the Chairman of the body concerned.
   e. The Nominating Committee to propose candidates for President and 2 General Council Vice Presidents only. It will be composed of 3 junior Past Presidents, senior member to be Chairman, and those General Council members elected by the Sections whose terms expire in year of election.
5. **Emergency Action:**
   Power of emergency action delegated to the individual Executive Committees associated with either the institutional or individual membership in cases where the time element is too critical to permit deliberation by the Executive Board; such actions to be reported to the Executive Board.

The Research Corporation and Its Service to Engineering and Scientific Research*

The Research Corporation was founded through the efforts of Dr. F. G. Cottrell in 1912, subsequent to his offering the Cottrell precipitator patents to the Smithsonian Institution.

The offer to the Institution involved the stipulation that these patent rights should be given an adequate business administration and the proceeds should be devoted to furthering scientific research. The first stipulation was beyond the legal activity of the Smithsonian Institution, and thus it was not possible for them to accept the Cottrell offer. Dr. Cottrell then proceeded to organize the Research Corporation for the purpose of introducing inventions into commercial use and to develop and administer them.

Historically, the problem of promoting the Cottrell patents extended back to 1905 when a volunteer group of scientists at the University of California met to formulate a procedure for successfully developing the inventions relating to electrical precipitation. Many subsequent conferences were held by this group in an attempt to commercialize the Cottrell patents. It was during this seven-year period of searching for a method of developing institutional scientific research that they reached the decision to make the proposal to the Smithsonian Institution.

This experience of Dr. Cottrell and the faculty of the University of California is quite typical of what happens in many of our universities and engineering colleges when an attempt is made to develop a worthwhile scientific invention through to the commercial stage. Too often banking interests look upon such developments as being entirely academic and impractical because they come out of an educational institution, and thus very little financial support is received from those who are in a position to commercialize the projects.

Under the stipulations of the Research Corporation charter, the net earnings were to be contributed to the Smithsonian Institution or other scientific societies and organizations as might be selected by the Board of Directors to conduct scientific and engineering investigations, research, and experiments. Briefly, therefore, the corporation was organized to hold and promote patents and to encourage and stimulate further research. That these purposes have been adhered to is evident from a recent listing by the Research Corporation of its major functions:

"(1) Design, manufacture and installation of electrical precipitation and other equipment arising from patents owned

* Paper prepared for the JOURNAL OF ENGINEERING EDUCATION by W. R. Woolrich, President of the Engineering College Research Association, and Dean of the College of Engineering of The University of Texas. January, 1946.

administered by Research Corporation.

"(2) Management, in the public interest, of patentable inventions of many classifications which arise in educational and research institutions or which are otherwise given to, or purchased by, the Corporation.

"(3) Grants-in-aid of research in institutions." †

In an analysis made of the member groups of the Engineering College Research Association, the representatives from the several member institutions indicated that a considerable number utilize the services of the Research Corporation, especially in the management of their patentable inventions.

When the Research Corporation performs the function of administering the patents for an institution, it reserves the right to exercise selective judgment in acceptance of any particular invention. Its experience indicates that profitable management is possible only in the case of "carefully selected inventions." † While very useful assistance would be given to inventors by accepting all offerings, the Board of Directors has indicated that this would defeat the prime purpose of the Research Corporation and probably jeopardize its considerable endeavor. The Corporation maintains an expert staff of legal and technically trained persons who can administer diversified patents, seek out suitable licensees, negotiate proper license agreements, and exercise supervisory control over the quality of the product marketed to the public.

For the most part, the Research Corporation grants no exclusive licenses, but does have freedom of discretion in giving special consideration to licensees who are in a position to give an invention a worthwhile birthright. The Research Corporation has maintained a very flexible attitude in dealing with such situations. Since inventions do lead to a wide variety of relationships, it is quite necessary that a position of high adaptability be maintained by the Corporation in order to meet the requirements of any existing conditions, whether social or commercial.

While many of the universities of the United States have successfully maintained their own research groups, patent committees, or research foundations, there are many institutions that do not have a sufficient number of meritorious inventions to be in a position to afford the type of staff necessary to successfully commercialize inventive creations. Again, many of the state-supported institutions have very definite limitations in their charters which do not permit their making suitable contracts for the commercial development of patents and inventions. The Research Corporation is rendering a very useful service to such institutions and makes it possible for the research investigators in such institutions to proceed in their field of scientific research without spending many hours on patent management, which often is far removed from their field of activity and ability.

Probably the service of the Research Corporation which has been least utilized by the engineering experiment stations, bureaus, and divisions is the supplying of grants for worthwhile research projects.

The Research Corporation does make grants to research institutions that are well recognized. While grants are not

† Research Corporation. "A Review for the Period 1912–1945." New York, 1945.

made to individuals, in considering the application of an institution for a grant, the qualifications of the research worker and the adequacy of his facilities, as well as the scientific merit of the proposed research, are given primary consideration.

The Research Corporation has no rigid policy with regard to its grants. For the most part, the grants have been made in the field of the physical sciences and in engineering, but they have often included the biological sciences. The record shows that by October 31, 1944, research grants had been made to the total of $1,279,637.

The Research Corporation is now very much concerned with the restoration of research in the colleges of engineering and especially in the smaller colleges and universities. Quoting a recent statement of its Board,

"In many instances able research men have been drawn into war activities either in the military services or in war research groups under Government auspices. It is of utmost importance to the future of scientific education in America that provision be made for the return of a maximum number of these men to the institutions of their former attachments or similar ones. In some instances the funds of educational institutions are likely to be insufficient for the full discharge of the responsibilities thrust on them by the historic events of recent years. In such cases research is peculiarly liable to suffer. Research Corporation is accordingly formulating a policy of grants to institutions in aid of research specifically designed to meet this situation." †

The Society for the Promotion of Engineering Education and the Engineering College Research Association are both vitally interested in this policy of the Research Corporation and urge that more of their member institutions contact the Research Corporation of New York concerning worthwhile proposals of engineering and scientific research that would be of mutual benefit to the institution, to the Research Corporation, and to society at large.

Analytical Statistics in Industry

By HOLBROOK WORKING*
Food Research Institute, Stanford University

One of the fields in which scientific developments of late pre-war years were applied widely and profitably during the war was the industrial application of analytical statistics. This war-time extension of the application of science was unlike many others in that it rested primarily not on the invention of new devices, but on education in concepts and techniques. It will have continuing educational significance because analytical statistics are as useful for industry in time of peace as in time of war. The need has been shown for continuing the education of men in industry in analytical statistics, and for revision of curricula of engineering schools so that engineering graduates of the future shall have knowledge of this subject now evident as fundamental to their professional work.

The War Problem

The major war-time extension in use of analytical statistics in industry occurred in its application to manufacturing, inspection and engineering problems. Prior to the war statistical analysis had found a substantial place in industrial research, and descriptive and analytical statistics were widely used in office problems of both manufacturing and commercial establishments; but statistical methods were virtually unknown in manufacturing operations or in most of the activities of engineering departments. Statistical tools had been developed, however, which were widely applicable in such uses, and much experience had been acquired by a few concerns in the use of these tools. The principles and methods involved had grown into a fairly clear-cut body of knowledge under the generally accepted name of Statistical Quality Control, which was derived from the title of a book published in 1931 by Dr. Walter A. Shewhart of the Bell Telephone Laboratories, a pioneer in the development of some of the more important statistical methods and in their industrial application.

Extension of the use of principles of mathematical statistics in industry hinged in part on the invention of certain devices—primarily sampling tables and the statistical control chart—but, as I have remarked, it depended more particularly on education. Reasonably complete exploitation of the advantages of statistical quality control in a manufacturing establishment commonly requires at least an acquaintance with certain concepts and principles of

*Dr. Working, Economist and Professor of Prices and Statistics at Stanford University, joined the staff of the Office of Production Research and Development, War Production Board, in April 1943, to assist with a program of developing use of statistical quality control in war industries, and was in charge of that program from September 1943 through July 1945.

mathematical statistics and of their possible applications in industry on the part of people in a wide range of positions in most departments of the organization. Something could be done toward assisting war industries to economize man-power and materials and to improve product quality by statistical means merely through technical training of a few specialists in each establishment, but attainment of the major advantages available required an educational program that could reach industrial personnel in a wide range of positions of responsibility. It required also facilities for providing technical guidance and competent assistance on occasional difficult problems to men in industry who had to be encouraged to use statistical analysis on the basis of a rather slender training. These needs have not ended with the war.

The principles and methods of analytical statistics which go under the name of statistical quality control are concerned with product specifications, analysis of production processes, routine process control, design and control of inspection procedures, and rationalization of acceptance specifications. These diverse uses, touching most of the engineering and production divisions of a manufacturing organization, are closely interrelated and they must be administered by persons whose primary responsibilities are non-statistical. The production processes subject to routine statistical control include automatic mechanical or chemical processes, processes dependent largely or wholly on human control, assembly operations, and adjustment of apparatus. Items on which statistical bases for acceptance may be used to advantage range from ball bearings to drugs to airplanes.

War-Time Development of Statistical Quality Control

Though this paper is concerned primarily with current educational aspects of analytical statistics in industry, it cannot ignore certain other influences that operated during the war. One of these was the adoption by most military procurement agencies in the United States of statistically-based procedures for inspection of materials submitted for their purchase.

The Ordnance Department of the Army was the first to take substantial steps in this direction. By the summer of 1942 it had such procedures in effect for the inspection of a wide range of small items purchased in great quantity; it had introduced a revolutionary principle in the use of statistical control charts in connection with the testing of armor plate for acceptance; and it had extended its use of statistical tests as a means of providing ammunition of all calibers with which superior accuracy of fire could be maintained. Other divisions of the Army, notably the Quartermaster Corps and the Signal Corps, and the principal procurement agencies of the Navy, were soon to follow in adoption of statistical principles for acceptance inspection, and to make advances in some respects on the methods initially adopted by Army Ordnance.

The use of statistical principles in acceptance inspection is only a small part of statistical quality control, but the adoption of that part by the chief procurement agencies of the armed services did much to arouse the interest of war industries in the possibilities of the methods in general.

Early in 1943 the Office of Production Research and Development of the War Production Board, under the di-

rection of Harvey N. Davis, entered on a program of developing the use of statistical quality control in industry. That program, as planned initially by Paul T. Norton, Jr., Chief of the Industrial Processes and Products Branch of the O.P.R.D., was to combine investigational and consulting service for industry, and assistance with the educational program of Engineering Science and Management War Training of the U. S. Office of Education along lines that had been initiated at Stanford University in the summer of 1942. In the outcome, the O.P.R.D. program was more largely educational than was originally planned, because the staff available for the work remained so small as to require limiting its activities to those which promised the largest results, and the pressing needs of the educational program allowed time for only a minimum of consultation on statistical problems of individual concerns.

In 1941 and 1942 a few educational institutions offered evening courses in statistical quality control under the E.S.M.W.T. program. These courses filled a need for training of technical personnel for industrial establishments which had an existing organization for statistical quality control, but they failed, then and later, to provide a sufficient basis for much extension of the methods to establishments where they were not previously in use.

In the summer of 1942 Stanford University undertook to develop a type of course that would meet the needs for introduction of statistical quality control into establishments where it was previously unknown. The initial Stanford courses were a product of the pooling of ideas and efforts of W. Edwards Deming, of the Bureau of the Census and Bureau of the Budget, Washington, D. C., E. L. Grant of the Stanford Engineering faculty, at the time Institutional Representative for E.S.M.W.T. at Stanford, and myself. The courses were made possible by existence of the facilities of E.S.M.W.T. and by the willingness of its Director, George W. Case, to sponsor an unconventional type of course in a new subject. As developed and tried during the latter half of 1942, the plan comprised an intensive eight-day course designed primarily for men in responsible positions in industry, and conducted by a competent staff including at least one person with considerable experience in the industrial use of statistics, a subsequent series of five all-day class sessions at intervals of four to six weeks, and a good deal of individual consultation involving visits made by the instructors to the plants from which men had been sent to the course.

This was the educational plan which the O.P.R.D. undertook early in 1943 to foster and assist. Subsequent modification of the plan in the light of experience consisted chiefly in a rearrangement by which lectures which presented statistical quality control in broad perspective were brought together into the program of the first day of the course and announced as a special program for executives. This initial one-day program was usually attended by about twice as many persons as were able to remain for the full course, and proved a valuable supplement.

To permit educational institutions to assemble adequate instructional staffs for such intensive courses, it was necessary for the O.P.R.D. to provide one or two instructors for each course in addition to those who could be borrowed from other institutions or from

industry. The O.P.R.D., however, avoided furnishing a major part of the instruction in any course, holding to the policy that each should be primarily an educational enterprise of the sponsoring institution rather than of the War Production Board. The eight-day courses could have been given more easily and perhaps usually somewhat better by a staff of instructors that moved unchanged from one course to another than by staffs that were reconstituted for each course, always including at least one instructor from the sponsoring institution; but class meetings subsequent to the initial eight days, individual consultation on industrial problems, and the provision of part-time courses to supplement the intensive ones, were regarded as essential parts of the program, and the responsible persons in the O.P.R.D. believed that these educational obligations should be assumed by local educational institutions rather than by a central governmental agency.

Following initiation of the O.P.R.D. plan for assistance to educational institutions in the giving of intensive courses in statistical quality control, thirty-three such courses were offered by twenty-eight institutions. Two of these were given after it became necessary in the spring of 1945 for the O.P.R.D. to discontinue most of its assistance. These thirty-three courses plus the two earlier Stanford ones were attended by 1,950 persons. An additional 1,900 attended the special sessions for executives which were a part of all but the first two courses. Of the 1,950 persons who took the full intensive course, 230, chiefly officers, were from the armed services, 50 were faculty members of institutions of higher education, and over 1,650 were industrial representatives who came from nearly 800 different concerns. Among the industrial representatives were thirty-three from thirteen Canadian establishments and two from Australia: the works manager of a government ammunition factory and a representative of the Standards Association of Australia.

From the outset the intensive courses drew an attendance of high quality. Some, especially at the earlier courses, were people whose native abilities or whose positions in their organizations did not permit them to proceed effectively with the work for which the course was intended to prepare them, but such unwise selections diminished in frequency as industrial concerns became better acquainted with the nature of statistical quality control. The following tabulation provides an analysis by position of those in attendance at one of the latest courses.

The Australian representatives who attended intensive courses in the United States were instrumental subsequently in arranging for similar instruction in Australia. Canadians attempted to arrange an intensive course in Canada, but in view of the difficulty of assembling an adequate instructional staff and the availability to them of the courses in the United States, they contented themselves with getting part-time courses offered. These were tuition courses given at McGill University and the University of Toronto. In the United States, through helping to equip instructors as well as by stimulating a demand for trained persons in industry, the intensive courses contributed to a rapid expansion of part-time instruction in statistical quality control after the middle of 1943.

The intensive courses in the United States, all given under the E.S.M.W.T. program, provided 158 thousand stu-

Position	No. attending	
	Exec. program	Full course
1. President	1	—
2. Vice President	10	1
3. Executive Secretary	1	—
4. General Works Mgr.	1	—
5. Asst. General Mgr.	1	—
6. Factory or Plant Mgr.	8	—
7. Asst. Factory Mgr.	3	1
8. General Superintendent	3	—
9. Fact., Plant or Div. Superintendent	6	1
10. Asst. Plant Supt.	2	—
11. Prod. Mgr. or Supt.	6	2
12. Superintendent	6	—
13. Asst. Superintendent	4	—
14. General Foreman	5	3
15. Supervisor of Tools and Equipment	2	1
16. Foreman	5	2
17. Supervisor	4	—
18. Sales Manager	1	1
19. Service Manager	1	1
20. Merchandise Manager	1	—
21. Personnel Manager	1	—
22. Head, Statistical Dept.	1	1
23. Statistician	2	1
24. Economist	1	1
25. Chief Cost Accountant	1	—
26. Accountant	1	—
27. Supervisor of Training	1	1
28. Asst. Dir. of Training	1	1
29. Director of Research	1	—
30. Director of Laboratory	1	1
31. "Laboratory"	1	1
32. Chief Chemist	8	5
33. Asst. Chief Chemist	1	—
34. Research Physicist	1	—
35. Chief Metallurgist	3	—
36. Metallurgist	7	4
37. Chief, Analytical Sect.	1	1
38. Chief Engineer	6	—
39. Supervising Engineer	2	2
40. Consulting Engineer	1	1
41. Chief Ind. Engineer	2	—
42. Industrial Engineer	9	6
43. Chief Chem. Engineer	1	—
44. Chemical Engineer	1	1
45. Prod. or Process Engineer	9	5
46. Engineer (not Q. C.)	7	3
47. Chief Inspector (or Mgr. of Inspection)	36	19
48. Asst. Chief Inspector	12	9
49. Director of Q. C.	3	1
50. Asst. Director of Q. C.	1	1
51. Q. C. Supervisor	3	2
52. Q. C. Consultant	1	1
53. Q. C. Engineer	6	3
54. Q. C. Investigator	2	2
55. Technical Inspector	2	2
56. Inspector or Q. C. Foreman	14	4
57. Inspection Supervisor	7	5
58. "Quality Control"	4	4
59. Bank Official	6	—
60. Govt. Procurement Agency	32	22
61. University Faculty	3	3
62. Others	8	2
Total	282	128

dent-hours of instruction to the 1,950 persons who attended them. Part-time courses under E.S.M.W.T. provided an additional 250 thousand student-hours of instruction to 5,600 persons. In addition, a large number of courses were given in industrial establishments without academic connection and at least one concern had nearly 500 employees trained in quality control courses under the extension division of a neighboring university.

The instructional staffs of the intensive courses in the United States included over forty men who were members of college or university faculties at the time of their initial service as

instructors, fourteen from industry, and three from government service. About seventy other persons, chiefly from industry, gave special lectures at one or more courses.

Few, if any, of the instructors were prepared at the beginning of the program to give first-class instruction in all the aspects of quality control treated in the intensive courses. The plan of instruction was developed through the cooperation of instructors with varied backgrounds for contributing to the course, and new instructors were being trained throughout the life of the program. Most of the instructors were men with either a good grounding in mathematical statistics and much teaching experience or with special knowledge of industrial problems of quality control, who were able to fill some instructional need in connection with the course without special preparation. Nearly all those recruited for courses after the first three were given an opportunity to observe one of the intensive courses before they participated as instructors.

In the spring of 1944, at the suggestion of Director Case of E.S.M.W.T., a special course, given at Purdue University, was arranged for training instructors. It provided for attendance on one of the regular courses for industrial personnel, supplemented by two prior days of lectures and a subsequent day-and-a-half of round-table discussions. This instructor-training course, attended by 29 faculty members from eighteen institutions, might well have been repeated for additional groups of prospective instructors, but the O.P.R.D. staff was unable to assume the obligations for assistance with additional intensive courses that should have followed such further training of instructors.

The great extension in industrial use of statistical methods during the war created a place for societies to serve the interests of people engaged in applying such methods. Informal organizations which attendants on the intensive quality control courses were encouraged to form as a means of aiding advance of their own technical and scientific knowledge developed in most instances into active professional societies. Similar local societies were formed also in a number of cities of the United States and Canada where no intensive course had been given. The local groups in the United States very early began to aspire to a national organization. In response to a desire of most of these groups for competent advice and assistance in the formation of a national society, the Committee on Applied Mathematical Statistics of the National Research Council, which had been the original sponsor of a national program for extending the use of statistical quality control in war industry, made a study of the proposal and suggested procedures appropriate to the formation of a national society with substantial professional and scientific objectives. These suggestions were adopted by nearly all of the local societies in the United States and a provisional organization is now in effect.

Post–War Educational Needs

The education of industry in the use of analytical statistics was only well begun during the war. It will continue rather slowly, somewhat as before the war, if it is dependent mainly on books, journal articles and discussions at society and association meetings. It can proceed much more rapidly if peacetime provision is made for courses such as were available during the war.

Plans laid for post-war education in statistical quality control for men in industry should take account of the two fairly distinct educational needs that exist. One, for the training of technicians, is rather easily met by extension courses of the usual type. The other, for education of men in administrative and supervisory positions, seems to require a type of course which it is difficult for an educational institution to arrange without assistance from an agency specializing in such courses. Industrial concerns are prepared to pay for such instruction, and if it is not provided by existing educational institutions it may be offered by private commercial organizations, which may tend to operate on a promotional rather than on a sound educational level.

From industry's discovery of the usefulness of analytical statistics will come a demand, only slightly felt as yet, that institutions offering technical training to young people preparing to enter industry include in that training suitable education in statistics. This nascent demand will present two or possibly three problems for educational administrations. Most readily recognized and met, perhaps, will be the need for more and better courses in institutions of higher education to train statistical specialists. Industry will seek people of such training, faculty members will offer courses purporting to give this training, and students will elect them, with only such need for special administrative supervision as is required to see that the new courses are competently taught.

More difficult may be the adjustments needed to include in the basic training of engineering graduates the education in fundamentals of statistics which industry will expect of them. In many concerns now, men in positions for which a broad engineering knowledge is needed rate the understanding of statistical principles that they have acquired recently as equalling in importance the knowledge, gained earlier, of the principles of mechanics or of chemistry. In the future, a grasp of the principles of statistics will be expected of all engineering graduates. Engineering curricula being what they are, this new need will not be met without some stress in academic circles.

In a number of concerns which have undertaken wide use of statistical quality control, a need has been felt for teaching production and assembly foremen and operators and routine inspectors some of the simpler concepts and principles of analytical statistics. These people have found the instruction interesting and stimulating and their efficiency and cooperativeness have been improved thereby. Such experiences may foreshadow the introduction of some statistical principles into technical courses in secondary schools.

Binomial Coefficients

Derivation of a Formula

By HARRY SOHON

Assistant Professor of Electrical Engineering, University of Pennsylvania

Binomial coefficients are used in many branches of engineering and technology. Statistics, biometry, and quality control are only a few subjects that make use of these coefficients. For those who are not familiar with the term "binomial coefficient" we may say that the symbol and defining equation are

$$\binom{n}{r}=\frac{n!}{(n-r)!\,r!}. \qquad (1)$$

It is equal to the number of ways in which n things can be taken r at a time.

As an illustration of the use of binomial coefficients in quality control we present the following example. This example is hardly typical of recommended practice, the numbers used in the illustration having been selected to simplify the equations. Resistors are packed twenty in a box. A resistor is considered defective if its resistance differs by more than ten per cent from the nominal value. If no more than four resistors out of twenty are defective the product is considered satisfactory. It is not practical to test every resistor; therefore four selected at random from each box are tested.

Assume that there are exactly four defective resistors in the box. Then the probability that all four resistors selected are good will be equal to the number of ways four resistors can be selected from the sixteen good ones divided by the number of ways of selecting four resistors from the total number, twenty. This is

$$\frac{\binom{16}{4}}{\binom{20}{4}}=\frac{\dfrac{16\times15\times14\times13}{1\times2\times3\times4}}{\dfrac{20\times19\times18\times17}{1\times2\times3\times4}}=0.3756 \qquad (2)$$

which implies that we may expect 37.56% of the samples tested to be perfect.

The probability that three will be good and one defective is the number of ways of selecting three from the sixteen good ones times the number of ways of selecting one from the four bad ones divided by the number of ways of selecting four from twenty. We have

$$\frac{\binom{16}{3}\binom{4}{1}}{\binom{20}{4}}=\frac{\dfrac{16\times15\times14}{1\times2\times3}\,\dfrac{4}{1}}{\dfrac{20\times19\times18\times17}{1\times2\times3\times4}}=0.4623. \qquad (3)$$

The probability that two will be good and two defective is

$$\frac{\binom{16}{2}\binom{4}{2}}{\binom{20}{4}} = \frac{\frac{16\times15}{1\times2}\,\frac{4\times3}{1\times2}}{\frac{20\times19\times18\times17}{1\times2\times3\times4}} = 0.1486. \tag{4}$$

The probability that one will be good and three defective is

$$\frac{\binom{16}{1}\binom{4}{3}}{\binom{20}{4}} = \frac{\frac{16}{1}\,\frac{4\times3\times2}{1\times2\times3}}{\frac{20\times19\times18\times17}{1\times2\times3\times4}} = 0.0132. \tag{5}$$

The probability that all will be defective is

$$\frac{\binom{4}{4}}{\binom{20}{4}} = \frac{1}{\frac{20\times19\times18\times17}{1\times2\times3\times4}} = 0.0003. \tag{6}$$

These results are summarized in Table 1.

TABLE 1

Condition of Sample	Per Cent Boxes Expected
Perfect	37.56
One defective	46.23
Two defective	14.86
Three defective	1.32
Four defective	0.03
Total	100.00

From the table we should expect two or more to be defective in

$$14.86+1.32+0.03=16.21\% \tag{7}$$

of the samples. Now if the test shows that two or more are defective in 50% of the samples this would indicate that there are more than the allowable four defective resistors in each box of twenty; therefore steps should be taken to improve the process.

In the illustration it was assumed that each box contained only twenty items instead of two dozen or a gross because the binomial coefficients are not easy to evaluate when large numbers are involved. When coefficients involving large numbers are required and if tables are not at hand some approximate formula must be used. Generally this consists of using Stirling's approximation for the factorial forms in the exact formula, equation (1).

In this paper a different approximate formula is derived. The derivation is presented because there are various interesting steps and accompanying comments that may prove valuable to the reader. For example one expression for an increment is preferred over another although both are derived from the same considerations. In another part where we should prefer to use n we think we ought to use $n+3$ and then find that the most satisfactory choice is $n+0.5$.

It is hoped that the reader will appreciate the method of derivation as well as the usefulness of the resulting formula.

If we assume that n is an even number and substitute

$$r=\frac{n}{2}+m \tag{8}$$

into equation (1) we have, using y for the binomial coefficient,

$$y=\frac{n!}{\left(\frac{n}{2}-m\right)!\left(\frac{n}{2}+m\right)!}. \tag{9}$$

In this form it is an even function of m, that is, replacing m by $-m$ does not change the value of y.

If m is changed to the next larger value we have

$$\begin{aligned} y+\Delta y &= \frac{n!}{\left(\frac{n}{2}-m-1\right)!\left(\frac{n}{2}+m+1\right)!} \\ &= \frac{\left(\frac{n}{2}-m\right)n!}{\left(\frac{n}{2}-m\right)!\left(\frac{n}{2}+m\right)!\left(\frac{n}{2}+m+1\right)} \\ &= y\frac{\frac{n}{2}-m}{\frac{n}{2}+m+1}. \end{aligned} \tag{10}$$

The change in y obtained by subtracting equation (9) from (10) is

$$\Delta y=-y\frac{2m+1}{\frac{n}{2}+m+1}. \tag{11}$$

The binomial coefficient is an even function of m. The slope therefore is an odd function of m. Replacing m by $-m$ in equation (11) will not result in simply changing the sign; hence we are not satisfied with the increment given in equation (11).

Change m in equation (9) to the next smaller value and we have

$$\begin{aligned} y-\Delta y &= \frac{n!}{\left(\frac{n}{2}-m+1\right)!\left(\frac{n}{2}+m-1\right)!} \\ &= y\frac{\frac{n}{2}+m}{\frac{n}{2}-m+1}. \end{aligned} \tag{12}$$

Subtracting equation (12) from equation (10) gives

$$2\Delta y=y\left[\frac{\frac{n}{2}-m}{\frac{n}{2}+m+1}-\frac{\frac{n}{2}+m}{\frac{n}{2}-m+1}\right]. \tag{13}$$

This is an odd function of m and therefore is suitable for our purpose. This equation may be written

$$\Delta y=y\frac{-m(n+1)}{\left(\frac{n}{2}+m+1\right)\left(\frac{n}{2}-m+1\right)}. \tag{14}$$

We shall now change from the discreet variable m to a continuous variable x such that

$$m\Delta x=x \tag{15}$$

where Δx will be specified later.

$$\Delta y=-y\frac{(n+1)\frac{x}{\Delta x}}{\left(\frac{n}{2}+1\right)^2-\frac{x^2}{(\Delta x)^2}}. \tag{16}$$

$$\frac{\Delta y}{\Delta x}=-4y\frac{(n+1)x}{(\Delta x)^2(n+2)^2-4x^2} \tag{17}$$

$$=\frac{-4xy}{(\Delta x)^2\frac{(n+2)^2}{n+1}-\frac{4x^2}{n+1}}. \tag{18}$$

If n is a small number equation (1) is satisfactory and there is no need of an approximate formula. We are interested in the case where n is large

The second term in the denominator of equation (18) will become negligible as n increases; but if we now choose Δx appropriately the first term can be made to approach any number we please. We might choose Δx such that

$$\frac{(\Delta x)^2(n+2)^2}{n+1}=b. \tag{19}$$

For n very large this is the same as

$$(\Delta x)^2 n=b. \tag{20}$$

But if $n=100$

$$\frac{(n+2)^2}{n+1}=100\frac{(1.02)^2}{1.01}=\text{approx. } 103 \tag{21}$$

suggesting that we use

$$(\Delta x)^2(n+3)=b. \tag{22}$$

We shall delay decision at this time and choose Δx such that

$$(\Delta x)^2(n+a)=b, \tag{23}$$

where a and b are constants. Later we shall find $a=0.5$ is the best choice!

Making this substitution and letting n approach infinity and Δx approach zero we have for the limit of equation (18)

$$\frac{dy}{dx}=-\frac{4xy}{b}. \tag{24}$$

The general solution of this differential equation is

$$ln\frac{y}{C}=\frac{-2x^2}{b} \tag{25}$$

or

$$y=Ce^{-2x^2/b}. \tag{26}$$

In order to evaluate the constant of integration C we use the following device. Consider the histograms in Fig. 1 where the heights are proportional to binomial coefficients, actually equal to terms in the polynomials

$$(0.5+0.5)^n.$$

For $n=2$

$$\frac{1}{4}+\frac{2}{4}+\frac{1}{4}.$$

For $n=4$

$$\frac{1}{16}+\frac{4}{16}+\frac{6}{16}+\frac{4}{16}+\frac{1}{16}.$$

For $n=6$

$$\frac{1}{64}+\frac{6}{64}+\frac{15}{64}+\frac{20}{64}+\frac{15}{64}+\frac{6}{64}+\frac{1}{64}.$$

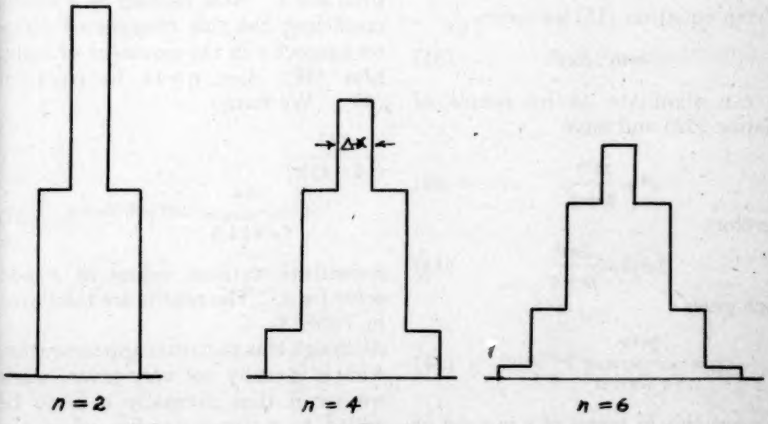


FIG. 1

The numerators of the various fractions are the binomial coefficients. The sum of the numerators equals the denominator and the area under each histogram is equal to unity. The width of each rectangle which represents Δx is equal to unity however. Consequently if Δx is not unity the area of the histogram will be equal numerically to Δx. Hence the area under the curve of equation (26) should be equal to $2^n\Delta x$.

$$\int_{-\infty}^{\infty} Ce^{-2x^2/b}dx = 2^n\Delta x. \qquad (27)$$

From integral tables we find the value of the definite integral on the left of equation (27) and have Δx given by equation (23).

$$C\sqrt{\frac{b\pi}{2}} = 2^n\sqrt{\frac{b}{n+a}}, \qquad (28)$$

$$C = \frac{2^{n+\frac{1}{2}}}{\sqrt{\pi}\sqrt{n+a}}. \qquad (29)$$

Substituting in equation (26) we have

$$y = \frac{2^{n+\frac{1}{2}}}{\sqrt{\pi}\sqrt{n+a}}e^{-2x^2/b}. \qquad (30)$$

From equation (15) we have

$$x^2 = m^2(\Delta x)^2. \qquad (31)$$

We can eliminate Δx by means of equation (23) and have

$$x^2 = \frac{m^2b}{n+a}. \qquad (32)$$

Therefore

$$2x^2/b = \frac{2m^2}{n+a} \qquad (33)$$

which gives

$$y = \frac{2^{n+\frac{1}{2}}}{\sqrt{\pi}\sqrt{n+a}}e^{-2m^2/(n+a)}. \qquad (34)$$

To get this in terms of r instead of m we use equation (8)

$$y = \frac{2^{n+\frac{1}{2}}}{\sqrt{\pi}\sqrt{n+a}}e^{-[2[(n/2)-r]^2/(n+a)]}. \qquad (35)$$

We are satisfied that this is a good approximation when n is large. If n is large the value of a will not be important. We therefore adjust a to make equation (35) good for small values of n. Let $r = n/2$. Then

$$y = \frac{n!}{\left(\frac{n}{2}!\right)^2} = \frac{2^{n+\frac{1}{2}}}{\sqrt{\pi}\sqrt{n+a}}. \qquad (36)$$

We substitute various values of n and solve equation (36) for corresponding values of a. The results are given in Table 2.

TABLE 2

n	a
2	0.546
4	0.527
6	0.520
8	0.516
10	0.51
12	0.51
14	0.51

This indicates that $a = 0.5$ should be satisfactory. This is quite different from $a = 3$. Now as long as a in the coefficient has this unexpected value we suspect a in the exponent of equation (35). Let $n = 14$ in equation (35). We have

$$\frac{14!}{(14-r)!r!} = \frac{2^{14.5}}{\sqrt{\pi}\sqrt{14.5}}e^{-[2[7-r]^2/(14+a)]}. \qquad (37)$$

Substitute various values of r and solve for a. The results are tabulated in Table 3.

Although this variation appears rather wide it is really not very severe when we recall that normally a is to be added to a large number when the

TABLE 3

r	a
2	−0.23
3	0.26
4	0.60
5	0.83
6	0.97

formula is used. An average value is near 0.5 giving

$$\frac{n!}{(n-r)!r!} = \frac{2^{n+\frac{1}{2}}}{\sqrt{\pi}\sqrt{n+\frac{1}{2}}} e^{-[2[(n/2)-r]^2/(n+\frac{1}{2})]}. \quad (38)$$

This formula has been worked out for even values of n. The derivation should now be inspected to see what the effect will be of using an odd value of n. This phase of the problem is left for the interested reader to try for himself. This formula will be found to work rather nicely for computing probabilities because of the two exponential expressions. By multiplying numerator and denominator of the coefficient by $\sqrt{2}$ and the numerator and denominator of the exponential fraction by 2 the formula can be made to look a little better

$$\frac{n!}{(n-r)!r!} = \frac{2^{n+1}}{\sqrt{\pi}\sqrt{2n+1}} e^{-(n-2r)^2/(2n+1)}. \quad (39)$$

Origin and Development of Cooperative Courses at the University of Cincinnati*

By CLYDE W. PARK

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Although most of the happenings reviewed in this paper date back nearly forty years, my purpose in recalling them is not primarily historical. If we are not careful of our emphasis we are likely to treat the past as something that is over and done, and not as something that has significance for the present. This is particularly true of happenings that are identified with the name of some outstanding person who has passed on. Thus, without realizing it, we convey the impression that Cincinnati's achievements in music belong to the period of Theodore Thomas; in art, to that of Frank Duveneck; and in education, to the time of Herman Schneider. Yet the chief reason why these dynamic leaders are remembered is that each of them inaugurated a vital tradition. Their ideas were not only valid for their own time but were also an inspiration and a challenge to succeeding generations.

Herman Schneider is remembered chiefly for his originality in devising a new approach to an educational problem. He also created a method, but he was not interested in formulating a rigid plan. The "cooperative system," as it was called, was simple in outline and flexible in operation. Because of its varied and far-reaching applications, it might better be referred to as "the cooperative idea."

The preliminary stages in the development of Schneider's idea are so well known that they need be reviewed only briefly in this connection. Seen in retrospect, such a development appears quite logical in view of the conditions in education and industry which prevailed around nineteen hundred. Engineering education had evolved slowly through the nineteenth century. Except in a few technical colleges which had originated as such, and in the non-agricultural divisions of the "A and M" colleges, the training of engineers was carried on largely by certain departments of the colleges of liberal arts. This arrangement was not without some important advantages. For providing intellectual discipline, cultural training and the mastery of fundamental science, the Arts college of the Victorian period has been justly praised. Naturally, the learning that it imparted was abstract, and the campus had a monastic detachment which was one of the most persistent of college traditions. In the last decade of the nineteenth century, teachers of engineering had become a distinct

*A paper given at the Fall Meeting of the Cincinnati Section, American Society of Mechanical Engineers, Cincinnati, Ohio, October 3, 1945.

group, represented by the newly organized "Society for the Promotion of Engineering Education." Their separate identity and specialized function was thus thrown into sharper relief. So was their relationship to the industries, whose growth in that period was creating a greatly increased demand for trained engineers. Up to this time it may be noted, the industries themselves had maintained an isolation as complete as that of any university campus. Their personnel consisted largely of "self-made" technical men who had come up through the shops. Secure in their practical knowledge, these men often looked upon college folk with unmitigated contempt, an attitude that was cordially reciprocated. But practical men had their limitations, and these in turn might become limitations to the growth of industry at a time when research and design were more important than they had ever been. Plainly the industries that used engineers and the colleges that trained them needed a closer understanding of each other as a basis for working out their common problems.

Somewhat brashly, for a young college instructor, Herman Schneider proposed a simple and direct plan for bringing education and industry together. He believed that engineering students should be given both practical and theoretical training through alternate periods at college and at practical work. These periods, equal in length, were to be comparable also in educational value, since each would represent a progressive sequence from the elementary to the more advanced phases of study and experience. The sequences would be planned to emphasize the inter-relations between theoretical and practical aspects of engineering training. Through direct contact with the processes and equipment of industry in actual operation, the student-worker would have the benefit of a complete and up-to-date laboratory of applied science, while industry would have the services of an alert young employee trained under practical conditions. During his "work period" the student would receive pay at the standard rate and would otherwise have the status of a regular employee. Upon graduation from college, assuming that he made good and found the work congenial, he would become a full-time instead of a half-time worker.

Schneider's enthusiastic advocacy of his plan, his efforts to "sell" the idea to his colleagues at Lehigh University and to such firms as Westinghouse and the American Bridge Company, the mixture of encouragement and rebuffs he received, his patience and persistence in renewing his campaign—all this is a long story, but one that is fairly well known. His first real progress did not come until 1903, when, after a last-minute change in his plans to go to the University of Wisconsin, he became Assistant Professor of Civil Engineering at the University of Cincinnati.

Continuing his efforts to obtain a trial for his cooperative plan, Schneider received definite encouragement from the mechanical engineering industries of Cincinnati, particularly the machine tool manufacturers. His first convert was John M. Manley, Secretary of the Cincinnati Metal Trades Association, who learned of the cooperative idea through a brief newspaper item reporting a talk Schneider had given to a local group of mechanical engineers. Mr. Manley accompanied Schneider on a series of visits to Cincinnati manufacturers who might become employers of cooperative students if and when the

plan were put into operation. When the response became sufficiently promising to warrant the making of definite plans for an experimental class of cooperative students, Schneider received powerful support from two manufacturers who were members of the University's Board of Directors: Ernest DuBrul and Frederick A. Geier. Many industrial leaders outside Cincinnati commended the plan from the beginning. Among these were Charles F. Kettering and the late John H. Patterson.

An initial cooperative class of twenty-seven entered the University in September, 1906. The progress of these young men, and of other and larger classes which followed, was watched with great interest, both locally and nationally. The *American Machinist*, which had published an outline of the cooperative proposal in 1905, opened its columns for annual reports by Schneider concerning developments in the operation of the plan. The gradual growth in number of students, range of industries and types of cooperative employment makes a statistical record that plainly spells "Success." For example, the enrollment had reached 450 by the beginning of the First World War, and students were employed by 35 different firms. The course was suspended for the duration, then post-war expansion brought the enrollment to 1,800, where it was stabilized. By this time the number of employing firms had increased to 300, and the geographical "radius of cooperation" had been extended to 500 miles.

Of the many observations concerning the effect of industrial contact upon the student, I shall mention only one in this brief discussion. It was noticed from the start that the student was stimulated to think about principles and explanations underlying the machines, processes, and labor relations which he encountered in the shops. He asked questions on the job and he brought questions back to the University each time he returned from work. In other words, the coordination between theory and practice did not wait to be brought up in the classroom—though it was discussed there. It began in the student's own observation and questioning. His firsthand contacts on the job gave a realistic turn to his thinking and induced a positive, definite attitude in his attack upon any problem. Because all written reports passed through my hands, I had an excellent opportunity to observe this realistic approach, partly in the choice of subjects, but even more in the way the subjects were handled. Examples could be cited without limit. One day two upper-class students brought in for criticism a report they had writen on a study of "the effect of compression ratio on a gas engine." They debated certain points with the positive knowledge that comes only from direct experience. One of these young men was the same Walter Tangeman who is taking part in this symposium tonight. As in the case of many other former "coops" who have become industrial leaders, I can say that "I knew him when." A student who brought in a paper on "Time-setting on Planer Operations" was similarly qualified to discuss his subject, because he had done time-setting and knew all about planer operations. He was already well on his way toward his future position of Superintendent of Production in a large machine tool plant. Of course discussions like this were especially welcome to a teacher of English. A composi-

tion is always better if the writer is interested in his subject, knows something about it, and has a motive for discussing it. All of these requirements were fulfilled in the papers which came from industrial laboratories and shops.

Since my part of the symposium this evening has to do mainly with the beginnings of the cooperative plan, as introduced by Herman Schneider at the University of Cincinnati, I shall omit any extended reference to later developments. There is a great abundance of printed matter covering applications of the plan in different institutions and in various industries. One document not as yet available which I hope will soon be published is a comprehensive report which has just been made on "The Aims and Ideals of Cooperative Education." The committee which has prepared this report for the cooperative section of the Society for the Promotion of Engineering Education, consists of Dean C. J. Freund, University of Detroit, *Chairman;* Acting President R. C. Disque, Drexel Institute of Technology; Dean R. C. Gowdy, College of Engineering and Commerce, University of Cincinnati; and Professor F. G. Seulberger, Northwestern University. The summary made by these men is equally valuable as a review of the past and as a sailing chart for the post-war period.

In view of the record so far, it seems likely that the system which had its modest beginning at the University of Cincinnati in 1906 will play an important part in the educational programs of tomorrow. Certainly that will be true if history repeats itself and a period of expansion occurs comparable to that which followed the First World War. My own present mood suggests a final word of caution, rather than prophecy. What the cooperative system can do has been demonstrated. What it will do hereafter depends. The dislocations caused by the latest World War have been far greater than those of a generation ago. The four-year eclipse of scientific training that has alarmed thinking people everywhere will have its effect upon engineering education, including the cooperative type. Then, too, it should be remembered that the cooperative system is not automatic. It needs something more than formal endorsement or lip service. It calls for administrative alertness, adaptability and enthusiasm, together with an absorbing interest in young people's careers. Because it is a vital principle it will withstand opposition, but it can suffer impairment if it is neglected or sold short by its friends. The contribution which it can make in the training of young people is unquestionably needed. Given an opportunity, the cooperative plan should prove more effective than ever in promoting team work between education and industry.

Humanistic-Social Studies in Engineering—Another Viewpoint

By S. F. BORG

Assistant Professor of Aeronautical Engineering, Postgraduate School, U. S. Naval Academy

Perhaps the favorite topic of discussion among engineering educators today concerns the "humanization" of engineering education. Hardly a month passes but that one or another engineering journal contains an article which will point out the so-called weaknesses of our present engineering curricula insofar as humanistic studies are concerned. We are advised, almost hysterically, to wake up and do something—fast—before it's too late. Engineers need, we are told, more English courses, more sociology courses, more history, more economics, more of everything, in fact, except engineering.

Let's get down to fundamentals. An engineering course is supposed to train a man for the engineering profession. An engineer differs from the arts or home economics or business administration student in that he, as an engineering student, was trained in engineering.

Just exactly what does prepare a man for engineering and eventually gives this man the right to call himself an engineer? Surely not the fact that he studied the same courses as the accountant or arts student, with the exception of perhaps a handful of fundamental engineering courses—possibly just enough to hopelessly confuse him and thoroughly unprepare him for his later responsibilities in engineering.

Engineering is growing up. The golden age of engineering rises before us—challenging, yet holding forth promise of engineering wonders as yet undreamed of. Before us also lies the opportunity that we, as engineers, have been waiting for—the chance to lift our profession to a station of dignity on par with the medical and law professions. Before us lies the opportunity to rise completely above the pseudo-engineers who are working in the mechanics trades or are included in the sales organizations of so many firms.

We are told that the engineer is not reading Plato, hasn't read Shakespeare, is not interested in the economic conditions of the tribes of Outer Mongolia and can't prattle properly across the dinner table. Therefore he is a failure as a citizen and it is the duty of the engineering school to correct this condition.

Surely an engineer who is interested in economic problems or who enjoys Shakespeare will read books on these subjects and be prepared to discuss them at greater length than the engineer who studied economics and Shakespeare during his college course and considered the subjects a drudgery at that time. Also, an engineer can read an authoritative daily newspaper (including the editorial page) without

having taken an English course in college. Who will then say that he is less well informed than the engineer who took a college course in modern civilization but who thereafter decided that his daily newspaper fare will consist only of Superman and the racing forms?

It is not "humanization" that the modern engineer will look for in his college course. Let us train him in engineering. Let us prepare him for the engineering field, the scientific engineering field, of the future by giving him a complete and thorough background in engineering. The present four year course will not then admit very many humanistic courses. As an educated man, an engineer will then round out his humanistic side in accordance with his inclinations and abilities—which he would do in any case, "humanistic" engineering course notwithstanding!

ERRATA

On page 283 of the December 1945 issue of THE JOURNAL OF ENGINEERING EDUCATION, the third line in the second column of the article—Necrology, the word should be consequence instead of consequently.

THE OHIO SECTION will meet in Columbus at the Ohio State University for an all-day session on Saturday, April 13, 1946.

S. B. FOLK, *Chairman*

Servomechanisms Courses—Their Pedagogic Value*

By DONALD P. CAMPBELL

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The widespread use of precision instruments and automatic control systems throughout industry and research today is almost incomprehensible. In our business and social lives similar devices are gradually appearing which not only expedite the work we do, but which also increase our pleasure and well being. Both the layman and the scientist find speculation upon future applications of instruments and automatic control systems interesting and fruitful because there are few situations in everyday life where such devices cannot be used effectively.

The general interest in instrumentation and automatic control creates an educational problem calling for fertile creativeness and intentive thinking. Men of all walks of life, from the man of the street to the professional engineer or scientist, demand to know more about the theory, construction and use of these instruments and control systems. No single training program or university plan could meet their collective needs, because the difference in intellectual needs is too great and because the general science of instrumentation and control has not yet been so firmly established that it warrants elementary translation. Nevertheless, the university and industry have partially solved portions of the educational problem already and vigilance in both groups will ultimately provide the desired training for laymen, salesmen, designers and scientists.

Courses for training graduate engineers in instrumentation and automatic control have been in effect for some time at M. I. T.,* and a few other schools have offered similar training programs, but the question must be answered, "Should more engineering training courses in instrumentation and automatic control be inaugurated in our engineering schools and universities?"

The magnitude of the professional need for engineers trained in the subjects mentioned clearly indicates that more instrument and control training programs should be inaugurated throughout p r i n c i p l e engineering schools. However, care must be exercised when establishing new programs or when augmenting existing ones, that pedagogical practices which might be

* Original paper published by *Instruments Magazine*, November, 1945; rewritten November, 1945.

* A series of courses in Instrumentation have been presented under the direction of Professor C. S. Draper in the Aeronautical Engineering Department. Likewise a series of courses in Servomechanisms Theory under the direction of Professor G. S. Brown are given in the Electrical Engineering Department. Close liaison has been accomplished by the two departments because the material in both groups of courses are related in such a manner that the students desiring to study Instruments or Control Engineering must be acquainted with both subjects.

established during the pioneering era in these sciences do not tend to be inadequate later. A sound approach to the broad educational problem may satisfy the immediate need of training instrument and automatic control personnel, and may also influence future trends in engineering education.

The Servomechanism Theory Courses presented at M. I. T. exhibit definite influential possibilities with regard to general engineering education. The pedagogical values which are prevalent are: The general integration of the individual courses presented in the undergraduate program into a well-rounded engineering background; the destruction of unnecessary barriers now existing between the various engineering branches; and finally the creation of persevering tendency toward self-education. Similar or even the same results may be attributed to any number of engineering courses, but a unique opportunity seems to be present in Servomechanisms Theory because of the particular nature of the subject and the objective which has followed in its presentation. Evidence shows proper balance must exist between theory and reduction to practice in this particular subject moreso than in most undergraduate courses. Although automatic control theory can be formulated completely as an abstract science, all branches of engineering contribute practically in both the types of equipment used and in the engineering techniques used.

The foregoing statements regarding the pedagogic value of Servomechanisms Courses can be better evaluated if one has a knowledge of the history of automatic control and an appreciation of the present-day state of the science. Since the middle of the last century, new ideas and new equipment emerging from the general engineering sciences were rapidly adopted and incorporated into automatic control theory and design. Today, as a direct result of this practice, we find that the theory of automatic control consists of a heterogenous conglomeration of mechanical, electrical, hydraulic, pneumatic, electronic, optical, pyrometric, and other engineering concepts. To find so many individual engineering branches actively represented in a single specialized subject of study adds greatly to the general interest in automatic control, but a complication is likewise present in the educational problem. Engineers *cannot be trained* specifically to enter any one sub-division of the field of automatic control when they graduate from technical schools. The justification of this conclusion is self evident when one considers a few of the specializations. Aircraft automatic pilot design, industrial process control, military fire control and gunnery, industrial machine control and computing machine design are only a few examples. However, the same training program in fundamentals used for process control groups can adequately meet the needs of naval fire-control and gunnery personnel, industrial-machine control personnel, aeronautical control personnel, and others concerned with very vital and active engineering problems in automatic control. Sufficient similarities exist among the varied interests to warrant the development of a *non-specialized method of instruction within a specilization.*

A plan for the establishment of automatic control courses in the university can be formulated. Such courses should embody fundamentals consolidated by liberal use of practical examples. The logical academic level for the subject seems to be in the graduate

school and certainly not beneath the calibre of a senior year engineering course. This plan is in direct agreement with the general philosophy of university education where the young engineer is taught fundamentals first and engineering practice is deferred until he enters professionally into industry. However, if automatic control engineers are to be produced, the existing educational philosophy must be modified because a thorough grounding only in the fundamentals is no longer adequate graduate training or even undergraduate training. The student must be sent out into the world with confidence and a good common sense ability for using the fundamentals to advantage.

The task is easier to cite than to accomplish, for the chaos existing in the average student's mind resulting from the unrelated manner in which fundamental theory courses are presented must be eliminated before formal instruction ceases. While laboratory courses are in general intended for this purpose, they cannot produce the desired overall result alone. A formal, carefully supervised course in the regular or the elective curriculum to provide the needed integration of fundamental theory must exist. The responsibility of aiding the student in the manner described cannot be relegated entirely to the university. Industry often erroneously concludes that the student upon leaving school should be filled with specialized information which will enable the company he enters immediately to realize a gain upon the investment. A revision is needed here in favor of the student, for he is now merely a mouthpiece or an automatic element in himself and rather than becoming a progressive thinker, he is often thwarted and falls by the wayside. Recognizing the obligations placed upon both the university and industry, let us now consider how the proposed program for training automatic control engineers can be accomplished.

The basis of the science of automatic control is the continuous control of the behavior of a prescribed time-varying quantity in accordance with some other predetermined variable which also may be time varying. The object of performing the control is to make available a device which is capable of replacing adequately a human operator ordinarily required to perform the task. Sometimes human physical limitations necessitate the use of automatic control; sometimes economic reasons dictate the policy. Often the complexity of the control to be accomplished exceeds the mental comprehension of a human. The type of apparatus chosen for automatic control systems usually operates upon the fundamental principle of comparing the controlled performance of the time-varying quantity with the desired quantity in such a manner that the error or deviation which exists between the two actuates the controlling mechanism. This concept is the keynote of the entire science.

To repeat is not redundant: *The Science of automatic control must be founded entirely upon the concept of studying the dynamical behavior of physical elements, physical systems, and combinations of physical systems, elements, and humans.* The starting point for effective educational planning lies here, but the dynamics referred to is not the pseudo-dynamics sometimes found in the elementary courses of mechanics and physical sciences, but an all inclusive dynamics aptly described by Sir Isaac Newton when he once said that there is only one science

of mechanics—dynamics and all studies of statics are special cases. Dynamics alone cannot serve as the foundation for building an automatic control educational program. Engineers live now in a world where practical, down to earth engineering usage of the physical theories must be accomplished by quantitative and not qualitative methods. Therefore, consider what influence the quantitative engineering approach has upon the educational problem.

The knowledge of how a process control system functions in detail or how a control system performs some specialized operation is insufficient information to enable a true understanding of the physical problems involved. The exact measure of how well the control performs must be known before the science is quantitative. Again let us refer to the statement of a great scientist for substantiation. Lord Kelvin once remarked. "When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind." Such an engineering attitude should be instilled in the student during university study. For example, the student should be aware that the design of a control system entails a detailed knowledge of the gallons of fluid per second flowing through valves, the amount of mechanical motion of control valves, the instantaneous acceleration of motors under the influence of torques, the duration of oscillations excited in the closed-loop, the instantaneous power required to produce the required controlling action and the like.

The prerequisites for the training which are essential if we are to produce men steeped in the philosophy of *quantitative dynamical engineering* are few but they are basic. First, the student should have a sound understanding of dynamics; second, he should have a broad knowledge of mathematics which he can use as a tool of engineering application; third, he should have a well-rounded knowledge of machinery, electricity, electronics, circuit theory, hydraulics, etc. from which he can draw the information he needs. Furthermore, the theoretical training and the laboratory studies which parallel the theory should bear close correlation. Although the burden placed upon the student is severe, here at last seems to be an engineering subject ideally suited for bringing the loose ends of the many components, making up an engineer's background, into one well-integrated whole.

If we assume that the student who wishes to enter automatic control engineering and instrumentation has the necessary prerequisites, it now becomes necessary to prepare a complementary program consisting of theory and laboratory courses to meet the established objectives. Theoretical study must be supported by confirmation in the laboratory of the principles expounded. A portion of the classroom work should be devoted to integrating the laboratory measurement problem with the theory. Also, as a part of the program, a definite effort should be made to refrain from the "easy-dose" coddling of the student in both the theory and the laboratory work. Not only a well-trained automatic control engineer, but a good sound thinking student able to follow an engineering career in any field will emerge if the suggested program is successfully executed.

To demonstrate that the suggestions

for training automatic control engineers are not theoretical ones, I should like to describe now in detail the program in Servomechanisms Theory offered at M.I.T. emphasizes the inherent pedagogic values which appear basic in the training of engineers and scientists, completely independent of the particular profession they choose. The graduate courses in the Theory of Servomechanisms comprise: (1) a course where the fundamentals of operation of closed-loop control systems are presented; (2) a later course dealing with the problem of servomechanisms design and synthesis; (3) laboratory courses given in conjunction with the advanced theory course for the purpose of providing a quantitative approach to measurement and design, and for developing an appreciation of the fact that all control systems are a collection of dynamic elements or instruments. The underlying philosophy of the graduate program is in essence the one which has already been outlined; namely, a quantitative presentation of the theory of analysis and synthesis of closed-loop automatic control systems from a dynamical point of view supported by laboratory confirmation.

To be certain that the conclusions derived from the coming discussions are valid, let us consider the status of the students entering these graduate servomechanisms courses before proceeding with a description of the material itself. The students are typical engineering graduates of high calibre, standing perhaps in the top one-fifth of their class; they are electrical engineers, mechanical engineers, areonautical engineers. Although there are always certain exceptions, the group exhibits year after year the same weaknesses; namely, a vagueness in their fundamental understanding of dynamics; a lack of confidence when writing differential equations to represent physical systems; a lack of effectiveness in the use of mathematics which they have learned. They have not integrated to any substantial degree the knowledge gained as an undergraduate and they are not capable of using information gained in one phase of their training to expedite work in another.

Deficiencies existing in the student's background must be offset in the first theory course if he is to understand the general overall problem of automatic control clearly enough to undertake the problems of design and synthesis in the advanced courses. The major part of our effort during the first semester is, therefore, directed toward creating in the student a feeling of genuine confidence in analyzing the behavior of control systems. This work divides into two sections: the first concerned with the establishment of the proper tools and techniques for performing analysis; the second, with the use of these tools and techniques on the fundamental control systems which constitute the backbone of the control engineer's working philosophy. Considerable attention is given to the problem of determining the transient response characteristics of closed-loop automatic control systems to arbitrary external disturbances. The student is required to write the differential equation which expresses the behavior of various control systems. He is required to solve these equations and he is expected to be able to derive from the results numerical answers to such typical questions as: How long will the transient persist in a particular control system excited by a certain external disturbance? What is the undamped natural angular frequency of oscillation of the control system? How

violent an oscillation can be tolerated in the performance of the control system in terms of the application? Exactly how would you adjust the control system constants to produce optimum dynamical performance? These questions cannot be answered by qualitative study; they require quantitative data. This creates one of the many interesting pedagogical problems. If the student must be quantitative, he must be given an appreciation for the general magnitude of the physical quantities which describe the equipment involved. The students popularly refer to this part of their training as "acquiring ball park numbers" representative of the machinery and the systems with which they are dealing.

Home problems are developed in which the physical constants of the equipment being studied are represented by typical numbers. Classroom derivations are terminated with a "reduction to practice" lecture whenever possible. Actual components and control systems found in modern applications are brought into the classroom, their operation is demonstrated, their constants are measured, and a direct correlation is made of the theory with the observations.

A representative classroom discussion may illustrate the value of the partial-demonstration lecture. A motor rated at one-fourth horse power is exhibited to the group. It runs at 3,600 r.p.m., and is a shunt field separately excited motor wound for reversible operation. The discussion is built upon these questions: What is a good round number for the moment of inertia for the rotor? If the armature current is held constant, what is the stall-torque per ampere of current flowing in the field windings? What is the ratio of the starting torque to the normal full load running torque? If a sudden voltage is applied to the field windings of the motor, what is the time required for the motor armature to reach substantially full speed in one direction or the other? If the motor is geared to an inertia load member to be controlled, what is the net inertia of the system referred to that shaft where the load exists. Incidentally, how is the problem of impedance matching in the mechanical system handled compared to the similar problem of impedance matching in electric circuit theory? No students feel that these questions are beneath their dignity. As the work extends into the more advanced phases, it is gratifying to observe students making a rapid estimate of the weight of a motor for an aircraft application or condemning a black-board discussion because they feel it does not contain enough down-to-earth facts.

The transient analysis approach to closed-loop control system analysis becomes complicated and laborious when extended to use on progressively more intricate control systems. New analytical tools for predicting and understanding the dynamical behavior of the more complex systems are found in the frequency response studies of the communications engineering theory. Although the information gained is quite different from that found in the transient approach, there is a convenient, readily understandable correlation between the behavior of a control system excited by sinusoidally varying disturbances and one excited by impulses. The sinusoidal method of analysis depends upon observing, in terms of a vector ratio, the relationship between the controlled response of the system and the excitation causing this response. Both the magnitude of the

vector ratio and the phase angle between the vectors can be plotted as a function of the excitation frequency.

Again a new type of thinking is demanded of the student, for one rarely finds engineers who will readily concede that a mechanical system, hydraulic system or a pneumatic system can be effectively studied by applying sinusoidally varying disturbances to it, or that the response can be represented to advantage as a locus in the complex plane. Nevertheless, the student soon finds a definite correlation between the width of the frequency band where no pertinent resonance effects occur and the general transient behavior of the same system. He learns that complicated control systems may have several independent modes of oscillation, some of which may exhibit predominant resonance effects, while others either exhibit slight resonance tendencies or none at all.

Again the concept of "ball park numbers" is valuable. The student must learn that mechanical systems consisting of heavy moving members will not oscillate at frequencies above a few cycles per second unless tremendous forces are involved. Furthermore, when systems of this nature show resonance in a manner not suitably damped, one can be almost certain that ultimate destruction of the equipment will occur.

The sinusoidal approach to control system analysis leads to thinking in terms of the transmission of data or information around the closed loop. The perfection of the elements of the overall system is measured in terms of the amplification and the phase shift of the signal as it passes through the various components. Terminology is borrowed from the electronic and communication fields by referring to the "gain" or the "amplification" and the "phase response" of the transmitted signal as a function of the frequency of the applied disturbance. The time has arrived for the presentation of the more profound tools facilitating control system *synthesis* when we glean this type of understanding among the students.

A function theory approach to the problem of representing the behavior of a dynamical system is necessary for accomplishing synthesis. The dynamic behavior of individual physical elements of a control system can be represented in terms of transfer functions and overall systems can then be synthesized by combining properly the dynamical response of the separate components mathematically, or graphically. Components of the controller not specifically defined can now be formulated in a clear and direct manner. Guess work is eliminated.

The theory course reaches its culmination at this point. The student finds that he has developed from a level where he was reticent to venture a prepared discussion of an analysis to a level where he desires to design and *build* new devices in the laboratory along carefully planned routes of scientific thinking.

The servomechanisms laboratory program commences with the simple one-afternoon type of experiment and broadens to the project type of experiment continuing for several weeks. Thus a wide variety of experimental possibilities permit the student first to gain a firm understanding in the fundamentals of quantitative measurement and later his study can be directed toward more extensive problems.

Elementary measurements made in the laboratory are concerned with the determination of the moment of inertia of motors and synchro armatures, the

elastance of springs, the damping forces produced in oil-filled dashpots, the torque-speed curves of prime movers (electric and hydraulic), and in general the static constants of typical control apparatus. Next, the student is required to measure the dynamic response for components of control systems, instruments and the simplest automatic control systems. Often these measurements are purposely made without the use of elaborate measuring equipment because our experience has indicated that many measurements can be made in a simple and direct manner with hardly more equipment than can be comfortably carried in one's coat pocket.

The advanced phase of laboratory work is planned once the student has mastered the fundamentals of measurement. Long range projects are selected, preferably by the student, which necessitate careful theoretical analysis, correlating measurement, synthesis, partial or total construction and test of the completed apparatus. The scope of the laboratory work can be illustrated by considering some of the projects undertaken by the student. Closed-looped speed control systems for controlling automotive engines have been studied by using electrical-mechanical analog methods. Components of automatic pilots for aircraft have been tested in an effort to improve the overall system performance; an automatic tracking telescope has been considered; and a wide variety of less comprehensive problems has been studied. Frequently, the problems are extended to the scope of graduate theses.

Summarization is difficult because of the numerous underlying themes which have led to the preparation of this paper. There is a definite need for extensive education in instrumentation and automatic control. The breadth of the training sought necessitates a division of the responsibility among industrial groups as well as the university. While certain specialized groups of control and instrument personnel can be effectively trained, these sciences are not yet in a suitable form to be presented to the layman. A limited number of schools offer courses in Instrumentation and Automatic Control, but the number of specialists trained is not adequate.

Servomechanisms courses seem ideally suited for providing a correlation of engineering theories and ideas. Interesting and up-to-date subject matter can be used from almost all the engineering fields for presenting the theory in a quantitative manner. At last a subject has been found which makes possible cross-fertilization of engineering courses at a lively and sparkling tempo.

Education for a Changing World

By BLAKE R. VAN LEER
President, Georgia School of Technology

Having seen the vast changes within the past decade wrought in the South by industrial development, a technological war, and reconversion of industry from peace to war and then back to peace, the writer will attempt to evaluate the many new problems and changes faced by the Georgia School of Technology and the other engineering schools of the United States and Canada.

Veterans and Other Students

The young man, who three, four or five years ago, swapped his slide rule and books for a rifle, his dormitory room for a tent or foxhole, and the peace and quiet of campus life for the muck and horror of war, is coming back to finish his interrupted education. But in his brief absence from the halls of education the world has moved forward and developed new scientific facts and knowledge which made possible radar, jet-propelled airplanes, the many marvels of electronics, and other objects unknown before the war. And in turn, the returning veteran, having been through the Gethsemane of blood and death and having been exposed to the spiritual devestation that war inevitably brings to the young and sensitive mind, will depend upon us as educators to rebuild his spirit and to rekindle his desire to learn. This "old" young man is our first and immediate problem in a changing world.

The next problem in order of importance is the "new" student, either a veteran who entered the armed forces upon graduation from high school or a recent high-school graduate. However, new and better techniques developed during the war for training engineers and others remain and should prove just as useful with him.

Besides teaching an engineering student the basic fundamentals of mathematics, physics, English, and the manufacturing processes of our today, we must teach the humanities and a sound philosophy of life based on objective truth, against which the various "isms," the hurricane of divergent political thoughts, and the gales of human destructive forces cannot prevail. Let us go back to the eternal and objective idealistic truth of the Bible. As engineering educators, it is our bounden duty to develop in our students, the great attributes of engineering: integrity, character, logical thinking, and habits of industry.

Once we teach the student these truths and develop the engineering attributes, we want to show him how to put these into effect, how through the channels of society to effect the mission of the engineer, which is—doing the greatest spiritual and material good for the greatest number. This means establishing in our college pattern and in our economic life a closer alliance

between the community and the engineer.

The Humanities of Engineering

For years statesmen, politicians, lawyers, generals and pedagogues have ruled our country and the world. Now, at last comes the era of the engineer—the era of the human engineer so clearly exemplified in the large scale problems of mass education, mass transportation, mass production, and mass redisplacement of the millions in Europe and the millions in our own country whose way of life has been changed by a war economy. To equip each of our students to deal with these problems, we have first to teach him about his fellowmen. Courses in political philosophy, sociology, personnel relations, community government, municipal planning, city management, and group psychology are indispensable.

Peace and world order imply not only a pooling of trade, of economic developments, but also a pooling of engineering and scientific knowledge. In view of this, the education of the engineer suggests comparative education, which is a knowledge of his South American neighbor, of his Russian ally's scientific progress, of the philosophy of his temperamental French cousin, and even of the forces which led a whole German people to embrace a totalitarian philosophy. This means broadening of the curriculum to include courses in foreign government, world trade, political philosophy, and foreign languages, and in addition, research in problems indigenous to European nations, to South American countries, and to the vast untouched field of Asiatic agricultural and industrial needs.

In establishing closer relationship between the community and the engineer in our own country, we are laying the groundwork for an era of industrial prosperity. Since the war has clearly shown the interpendence of country upon country, people upon people, community upon community, it is logical to expect that this trend will continue and will be directed more and more by engineers versed not only in technology but also in the humanities. Industry is asking for this type of engineer today and is willing to subsidize his training, to finance his research, and even to suggest the organization of his curriculum. Why? Industry knows it will directly benefit from his efforts to its own economic betterment. In return, the student will benefit from a clearly motivated and directly purposeful education.

Responsibilities of the Engineering Educator

A great responsibility rests upon the engineering teacher in this changing world—a responsibility to his students, to his community, and to himself. His responsibility to his students is to see that they are directed towards the field of specialization for which they are best fitted. Preliminary aptitude tests can detect certain latent traits that will help in this diagnosis. In other words, a mechanical engineer should receive technical training that will make him a better mechanical engineer. Following the decision on the student's field of specialization, the engineering teacher should then give the student the most purposeful and scholarly instruction of which he is capable.

In his responsibility to the community, the engineering teacher must be alert to the needs and desires of industry, state and nation for the various types of engineers. He creates them,

shaping abilities that may benefit his community at any specified time. A teacher existing in a vacuum does not create capable engineers. As the needs of a community are in a perpetual flux, so the education of the engineer should be adapted for timely communal needs. Just as present-day engineering education is concerned with industrial reconversion and development, construction and reconstruction, so the engineer of tomorrow must be trained in the specific future needs of the community. It may be prefabricated housing, mass city planning, air conditioning, or development of synthetic foods.

The engineering teacher has a responsibility to himself, as an individual. The period of academic isolation and the anti-socialism of the teacher is gone. The professional engineer is aware of his professional interrelation with society. So the engineering teacher owes himself the responsibility of keeping *en rapport* with the community in which he lives, and which he serves as a citizen. For in that way only can he train others to live in and serve it.

The Growth of Engineers

Engineers have grown great because more than any other group of public servants, they have anticipated the future of society's needs. Whenever society has reached a stage in its development when it was ready for a revolutionary change, an engineer has come forward to meet it. Witness Stephenson and his steam locomotive, Eli Whitney and the cotton gin, Edison and his electric light, and Taylor and modern management. More than any other group of public servants, engineers have raised the standards of living for the masses of people by emphasizing the necessity for technological developments which in turn made cultural and educational opportunities.

Today, the stature of the engineer and his work on behalf of society is being greatly enhanced not only because of the work of the professional engineer but also because of the engineering schools in his particular area. For example, safety on land and sea and in the air is being furthered by the radar research being carried on at M.I.T.; the peaceful application of atomic energy are being studied at the University of Chicago; and the development of resources and industries in the South is being assisted by the research work at the Georgia School of Technology. Since the writer is intimately familiar with the work of the last-mentioned institution, he will use it as an example of how the engineer can aid the development of an area or even a country.

Surveys carried out by engineers have shown that it is not possible to bring the per capita income of the South to a level comparable with that of the North and East without developing greatly the area's industries. This, it has been proved, can only be done through engineering and scientific research. There is no other way the South can find means of developing its natural resources and converting them from raw materials into useful manufactured products. As a result of research at Georgia Tech thus far, many industries in Georgia and the South have been developed or expanded and in this way much done to improve some of the poverty-stricken districts of the area. Needless to say, the stature of the engineer in the South is growing with each of these accomplishments.

Engineering Colleges Are the Schools of Today and Tomorrow

Our engineering schools today are sought after because of the universally practical training an engineering school offers. Dealing as he does, in facts and figures, mainly, the engineer can readily transfer his training to industrial administration, to governmental management, or to such non-technical fields as law, medicine, and theology, applying to each one not a hit and miss method of approach but a scientific one.

The mental and moral disciplines which are developed in studying the basic fundamental subjects in engineering are of tremendous importance. One cannot bluff his way through courses in mathematics, physics and chemistry. The student either knows the answer or he does not; he can solve the problem or he cannot and there is no argument about it. When the results are reviewed any competent outside person can determine whether or not the answer and the solution are correct. Thus a student is required to develop logical and accurate habits of thought.

The engineering curricula require for the four year baccalaureate from 25 per cent to 30 per cent more actual hours of work than is required in the average normal liberal arts curriculum. Thus at a time when many scoff at hard work and habits of industry, the engineering curricula insist upon them. That is the reason industries all over the United States and Canada seek the graduates of engineering schools. These young men are not only trained in the basic fundamentals of their profession but also in habits of industry and habits of integrity.

The time is coming when even the field of government, too, will be eager for the engineer's training in coping with large scale problems of city and state and national management. This development has been accelerated by the recent war.

The scientific advances in many specialized fields of engineering have been so rapid and so great that the volume of material available even in a very small highly specialized field is now so great that a young man cannot grasp it all in the four years of his college training. Therefore, engineering colleges should offer an additional year in graduate work or even extend the four years course to five years, as some engineering schools have already done. The graduate student should be encouraged, in fact required, to investigate new and unknown paths through the jungles of scientific ignorance. He should be taught to develop mental and technical resourcefulness, courage, and imagination on a much higher and greater level than we have any right or reason to expect from an undergraduate student. Only in this way can we meet the growing demand from industry and government for men trained as research engineers and scientists.

Fundamentals are Important

Whether we are teaching veterans or new students, it behooves us to be careful of our fundamentals. These fundamentals, as brought out in the preceding paragraphs, are: integrity of character; accurate, methodical and relentless logic; work habits of industry; and useful knowledge, which should include the humanities and political sciences. Engineering educators should never forget that the engineering students of today are the leaders of tomorrow.

The reconstruction and reconversion period now underway will hasten greater changes technologically as well as socially. Our problems of world production, world trade, and world distribution will necessitate the capable services of trained engineers if our country is to succeed as a world power. What better insurance of that success could we have than the character and capacity of the teachers in our engineering schools, who have brought us thus far in our civilization and in our scientific development? The engineering teachers are shaping the destiny of the world.

Engineering Physics as a College Curriculum

Progress Report of Committee on Engineering Physics, Physics Division

C. E. BENNETT, *University of Maine, Chairman*
J. W. WOODROW, *Iowa State College*
F. L. PARTLO, *Michigan College of Mining and Technology*

One of the first projects undertaken by the new division of Physics, authorized at the Cincinnati meeting of the S.P.E.E. in June 1944, was a study of the status of Engineering Physics curricula in engineering colleges by a committee appointed by the chairman of the Division, J. G. Potter. This is the first report of this committee.

An attempt was made to ascertain how many and what colleges offer the Engineering Physics curriculum, or one which might be construed as its equivalent. A letter and questionnaire were sent to the Head, or Chairman, of the Physics Department in each of the approximately 175 institutions listed as Institutional Members of S.P.E.E. in the February 1944 issue of the JOURNAL OF ENGINEERING EDUCATION. The returns provide the basis of this report. They seem particularly significant because 120 replies were received from the 175 questionnaires sent out. This represents a surprisingly high score for any questionnaire. Since any conclusions based upon a study of the returns of a questionnaire depend so much upon the exact wording of the questions and the instructions, the letter and the questionnaire are reproduced here in their original form as shown on pages 440 and 441.

The replies to the questionnaire fall into two groups according to a positive or a negative answer to the first question "Does your institution grant a degree in physics which might be interpreted as satisfying the above definition of Engineering Physics?" It is of interest to note that 46 institutions reported "yes" and 73 reported "no." Of the latter group, however, 17 institutions gave no degree at all in physics. In the institutions reporting "yes," several different names for the curriculum are reported, as indicated in table I, which also shows the college or division of the institution in which the curriculum is administered, and a yes or no answer to the question "Although your curriculum fits the above definition would it be described more properly as a physics curriculum in which a minor in engineering is listed?"

The institutions answering "no" to the first question are listed in table II according to the category in which they are interpreted as falling, based upon a study of the answers to question 3 "If you do not have such a curriculum, do you contemplate offering one in the near future?", question 4 "Do you have any interest in such a curriculum?", question 5 "Does your institution offer any degree in physics?".

DIVISION OF PHYSICS

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

J. G. Potter, *Chairman*

C. E. Bennett, *Secretary*

Executive Committee: H. L. Dodge, J. H. Howey, J. W. Woodrow

December, 1944

TO CHAIRMEN, DEPARTMENTS OF PHYSICS

Gentlemen:

A Committee of the recently formed Physics Division of S.P.E.E. has been appointed to consider questions relating to Engineering Physics. As a first step, it seems desirable to find out, if possible, how many and what institutions are granting degrees at the present time in Engineering Physics. The term Engineering Physics is used in this letter to indicate a curriculum in applied physics in an engineering atmosphere leading to a B.S. degree, whether or not it is administered in a college or school of engineering. Although it is felt by some that eventually this designation may be limited to a strictly engineering degree, the term does not have any universally accepted definition at the present time. In all probability it will never mean a rigid set of courses, the same for all institutions, but rather a curriculum in applied physics and engineering developed from a technological rather than a liberal arts viewpoint, and leading to a B.S rather than an A.B. degree.

You would be of great assistance to this Committee if you would answer and return the attached brief questionnaire. If the preliminary results should warrant it, a second questionnaire may be used for more detailed information. An analysis of this material will be presented at the annual meeting next summer to which you and your colleagues are invited, whether or not you are members of S.P.E.E. Incidentally, an increase in physicist membership would be a fitting appreciation of the council's action in creating the new Physics Division of S.P.E.E.

S.P.E.E. Committee on Engineering Physics

C. E. BENNETT, *Chairman* *

H. L. DODGE *

J. H. HOWEY

F. L. PARTLO

J. G. POTTER *

J. W. WOODROW

* Also members of the A.A.P.T. Committee on Cooperation with the S.P.E.E.

QUESTIONNAIRE

COMMITTEE ON ENGINEERING PHYSICS

S.P.E.E.

Please answer and return to C. E. Bennett, University of Maine, Orono, Maine.

1. Does your institution grant a degree in physics which might be interpreted as satisfying the above definition of Engineering Physics? .....

2. If your answer to the above is *yes*

   (*a*) Is it called "Engineering Physics" or "Applied Physics" or what? .....

   (*b*) Is the present name satisfactory? ..... or what would you suggest as a better name? .....

   (*c*) Is any special literature available to describe it? (The Committee would be pleased to receive it.) .....

   (*d*) Is the curriculum administered in a College or a Division of Engineering? ..... If not, where? .....

   (*e*) Although your curriculum fits the above definition, would it be described more properly as a physics curriculum in which a minor in engineering is listed .....
   If so, would you prefer a more closely integrated engineering and physics combination? .....

3. If you do not have such a curriculum, do you contemplate offering one in the near future? .....

4. Do you have any interest in such a curriculum? .....

5. Does your institution offer any degree in Physics? .....

   If so, what degree? .....

6. Comments .....

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Answered by .....

Title .....

Institution .....

TABLE I

Institutions Answering "Yes" to Question I:

"Does your institution grant a degree in physics which might be interpreted as satisfying the above definition of Engineering Physics?" Institutions are listed according to the name used for the curriculum.

Institution	Administration of curriculum. College of	Is curriculum better described as Physics major with Engineering minor?
(1) *Engineering Physics*		
Alabama Polytechnic Institution	Engineering	No
University of Alberta	Engineering and Physics	No
University of Colorado	Engineering	No
University of Illinois	Engineering	No
University of Kansas	Engineering	No
Lafayette College	Engineering	No
Lehigh University	Engineering	No
University of Maine	Engineering	No
Michigan College of Mining and Technology	Engineering	No
University of Michigan	Engineering	No
Montana State College	Engineering	No
Ohio State University	Engineering	No
Oklahoma A. and M. College *	Arts and Sciences	Probably not
University of Oklahoma	School of Engineering Physics	No
Queen's University	Engineering	No
South Dakota School of Mines	Engineering	No
South Dakota State College	Engineering	No
University of Tennessee	Engineering	No
University of Tulsa	Engineering	No
* Prefers the name applied Physics.		
(2) *Physics and Engineering*		
University of Pittsburgh	Engineering	No
(3) *Applied Physics*		
California Institute Technology	———	Yes
Iowa State College *	Science	Yes
University of Maryland	Arts and Sciences	Yes
Rutgers University	Arts and Sciences	—
Rensselaer Polytechnic Institute	Engineering	No
* Not satisfied with name.		
(4) *Industrial Physics*		
University of Akron	Arts College	Yes
University of Arkansas	Arts and Sciences	—
Clemson College *	School General Science	Yes
Kansas State College	Arts and Sciences	No
Louisiana State University	Chemistry and Physics	Yes
Virginia Polytechnic Institute	Engineering	Yes
Wayne University	College of L. A.	Yes

* Not satisfied with name.

TABLE I—*Continued*

Institution	Administration of curriculum. College of	Is curriculum better described as Physics major with Engineering minor?
(5) *B.S. in Physics*		
Polytechnic Institute Brooklyn	Engineering	Yes
Case School of Applied Science	Engineering	No
Georgia School of Technology	Engineering	No
Illinois Institute Technology	Engineering	No
Massachusetts Institute Technology	Engineering	—
University of Minnesota	Institute Technology	Yes
Missouri School Mines and Metallurgy [1]	Engineering	No
Pennsylvania State College [2]	School Chemistry and Physics	Yes
Rhode Island State College	Engineering	Yes
Rice Institute [3]	Academic	Yes
University of Rochester [4]	Physics Department	Yes
University of Texas	Arts and Sciences	Yes
Union College	Division of Engineering	Yes
Worcester Polytechnic Institute	Engineering	Yes

[1] Would prefer the name "Engineering Physics."
[2] Has considered "Industrial Physics."
[3] Honors in Physics. Not satisfied.
[4] Prefers "Physics for Engineering Students."

TABLE II

INSTITUTIONS ANSWERING "NO" TO QUESTION I

1. *Contemplating such a curriculum in the near future*

University of Alabama
Bradley Polytechnic Institute
University of California
Carnegie Institute of Technology
University of Cincinnati
Colorado A. and M. State College
Fenn College
Harvard University
Howard University
Johns Hopkins University
University of Kentucky
Marquette University
University of Nebraska
New Mexico College of A. and M.
North Carolina State College
North Dakota State College
University of Pennsylvania
Princeton University
Syracuse University
University of Utah
University of Virginia
Washington University (St. Louis)
University of Wisconsin

2. *Interested and possibly contemplating later (after war)*

The College of the City of New York
Clarkson College of Technology
University of New Mexico
New Mexico School of Mines
Oregon State College
State College of Washington
University of Wyoming

3. *Interested but not contemplating one*

Alfred State Agricultural and Technical School
University of Arizona
Bucknell University
Chrysler Institute of Engineering
University of Connecticut
The Cooper Union
University of Delaware
Detroit Institute Technology
George Washington University
University of Georgia
University of Idaho
Michigan State College
Mississippi State College
University of Missouri
University of Nevada
Newark College of Engineering
New York University
University of North Dakota

TABLE II—(*Continued*)

Northwestern University
Pratt Institute
University of Puerto Rico
Rose Polytechnic Institute
Southern Methodist University
Stanford University
State University of Iowa
Swarthmore College
University of Toledo
Tulane University
University of Vermont
Valparaiso University
Virginia Military Institute
West Virginia University

4. *Not interested*

Catholic University of America
Dartmouth College
Los Angeles City College
Manhattan College
Montana School of Mines
University of Nebraska
New York State College
Texas A. and M. College
Webb Institute Naval Architecture
Yale University

5. *Of the above institutions, the following do not offer a degree in Physics*

Alfred State Agricultural and Technical School
Chrysler Institute of Engineering
Clarkson College of Technology
Cooper Union
University of Delaware
Detroit Institute of Technology
Fenn College
*Franklin Technical Institute
University of Georgia
State University of Iowa
Los Angeles City College
Montana School of Mines
Newark College of Engineering
New Mexico School of Mines
Pratt Institute
Rose Polytechnic Institute
Webb Institute of Naval Architecture

* Not listed in table II.

TABLE III

SCHOOLS WITH AVAILABLE INFORMATION ON ENGINEERING PHYSICS *

University of Akron (Catalog Material, B.S. in Applied Physics)
Alabama Polytechnic Institute (Engineering Physics) General Statement and Curricula
Case School (Catalog Material, B.S. in Physics)
Clemson College (Catalog Material)
University of Colorado (Catalog Material, Engineering Physics)
Illinois Institute Technology (Bulletin)
University of Illinois (Descriptive paper and curriculum)
Kansas State College (Curriculum in Industrial Physics)
University of Kansas (Curriculum in Industrial Physics)
Lafayette College (Catalog Material, Engineering Physics)
Lehigh University (Catalog Material, Engineering Physics)
Louisiana State University (Catalog Material, Physics)
University of Maine (Published Material with curriculum in Engineering Physics)
Michigan College of Mining and Technology (Catalog Material)
Montana State College (Willing to help, Catalog Material)
Ohio State University (Catalog Material, Engineering Physics)
Oklahoma A. and M. (Catalog Material)
University of Oklahoma (Curriculum and Engineering Physics Bulletin)
Queen's University, Kingston, Ontario (Catalog Material, Physics)
Rensselaer Polytechnic Institute (Catalog Material)
Rhode Island State College (Catalog Material, Physics)
South Dakota School of Mines and Technology (Catalog Material, Engineering Physics)
University of Tennessee (Catalog Material)
University of Tulsa (Catalog Material, Engineering Physics)
Union College (Catalog Material)
Wayne University (Curriculum Material, Industrial Physics)

* Probably not a complete list.

TABLE III—(*Continued*)

TABULATED RESULTS

Number of questionnaires sent out	175	
Number of replies received	120	
Number giving Engineering Physics (based upon interpretation of respective department heads) as follows under each name:		
Engineering Physics	19	
Engineering and Physics	1	
Applied Physics	5	
Industrial Physics	7	
B.S. in Physics	14	
		Total 46
Number not giving Engineering Physics		
Contemplating in near future	23	
Interested and possibly contemplating later	7	
Interested but not contemplating	32	
Not interested	10	
In addition to the above but not giving any physics degree	1	
		Total 73
Number of replies from institutions not giving degrees in physics	17	
Number of "No" replies from degree granting institutions	55	
Compared with		
Number of "Yes" replies as noted above	46	
Number replying but not answering questions	1	

In table III are listed the institutions which have indicated on the questionnaire that literature is available describing the offering in Engineering Physics.

CONCLUSIONS

It is concluded by the committee that many institutions which grant a degree in physics give a degree in Engineering Physics according to the definition of Engineering Physics in paragraph one of the letter sent out. This is based upon 46 "yes" answers compared with 55 "no" answers. It, also, is concluded that there is considerable interest in Engineering Physics as indicated by the additional 23 institutions contemplating such a curriculum in the near future, and the added fact that such a large percentage of institutions replied to the questionnaire. More than half of the institutions responding are either granting the degree or are contemplating it in the near future. This represents appreciably more than one third of the institutions having institutional membership in S.P.E.E.

There is the further inescapable conclusion that a very large fraction of the institutions granting such a degree interprets the curriculum as an integrated combination of Engineering and Physics rather than a major in physics with a minor in engineering. Of the institutions using the name "Engineering Physics" only one disagrees, and in this same institution a different name would be preferred. Furthermore, the curriculum is administered for the most part by the division of Engineering of the respective institutions. At one institution, the University of Oklahoma, there is a School of Engineering Physics.

In view of the information gained from this questionnaire, it appears that

Engineering Physics is rapidly becoming an established curriculum in Engineering Colleges. By and large, those institutions which already have it are very much satisfied, and many institutions which do not have it appear to be contemplating it. The committee's next step should, in all probability, be to study the contents of this curriculum in the various institutions.

What About Our Faculties?

By H. P. HAMMOND
Dean, School of Engineering
and
E. A. WALKER
Head of the Department of Electrical Engineering and Director of the Ordnance Research Laboratory. The Pennsylvania State College

Recently an occasion arose for learning the future plans of members of the scientific and technical staffs of certain emergency war research laboratories. A good many of these men were former college teachers of science or engineering—some on leaves of absence, others under no obligation to return to teaching. Each of them was asked to state his plans: whether he wished to stay in research laboratories or industrial work; whether he planned to return to teaching; or whether he desired to seek another type of opening. He was also asked to give reasons for his plans. Response was voluntary. The results of these canvasses are interesting. They are summarized below:

Of the 129 replies to one group of inquiries, approximately one-half came from physicists, one-half from engineers, and small numbers from mathematicians and other scientists. Approximately two-thirds came from former teachers who were at the time in war research laboratories and one-third from former teachers in industry.

Of the 129 replies, 61 indicated probable return to teaching; 43 definite expectation not to return to teaching; and 25 probable non-return to teaching: totals 61 returning; 68 not or probably not returning.

The youngest group, instructors and assistant professors, showed a larger percentage not returning than the older group of associate and full professors.

There was no significant difference between the answers of those who taught graduate students and those who were limited to undergraduate courses.

The group from industry showed a greater percentage not returning to teaching than the group in temporary war laboratories. The reason for this is obvious.

Many of those who replied to the questionnaire took the opportunity to express dissatisfaction with certain aspects of teaching. Many indicated that salaries were too low or that there was not enough responsibility or time for research. In the group of 43 definitely not returning, 21 said the salaries were too low; 19 said the teaching load did not allow enough time for research; 6 said that the position required too little responsibility; 4 said they did not like teaching.

A second sampling was obtained from groups of former college teachers working in three large aircraft companies.* These responses were secured in July and September, 1945. They

* Messrs. W. E. Beall of Boeing Aircraft Company, C. T. Reid of Douglas Aircraft Company, Inc., and J. M. Wassall of Lockheed Aircraft Corporation contributed to the information and views quoted in this article.

are summarized below. It will be noted that they are in substantial agreement with the responses obtained from the canvass first cited.

Company A. — ". . . the results quoted in your letter are about what would be expected in any industrial laboratory; that is, not more than one-fifth of the former college professors would be inclined to return to university work. We have had a few cases in which some of our men returned to former college positions, but in most of these cases the man had not made out very well in our laboratory and we were not too unhappy to lose his services.

"A number of our best personnel have indicated their desire to spend part time continuing their university work in neighboring colleges for the purpose of keeping up to date on recent developments and, usually, to obtain an advanced degree. We consider that . . . the colleges would do well to encourage such arrangements. . . ."

Company B.—"The majority of them (former college instructors) a under age 30. This may have so bearing upon their attitudes expresse because presumably not many we firmly established in their professio occupations.

"At least half of them seem to ha in mind continuing on permanently work with industry. This is true spite of their fairly frequent expressi of disappointment in our kind of r search, which typically assigns a m to find a solution to a given desi problem, rather than giving him a fr hand to explore broadly in the field science.

"Those least inclined to remain industry (including a few who de nitely plan to return to college or u versity work) are, in general, the old men (in the age bracket of the fo ties)."

Company C.—"Twenty engine who had been affiliated with a colle or university participated. The r sults, in broad terms, are tabulat below:

Age Group	Number of Engineers	Reactions
20–29 years	5	Will not return to teaching because of insufficient salary and opportunity for advancement.
	2	Plan to return at later date. One wants more industrial research experience, the other wants his specialized experience to qualify him for a higher-paying job.
	1	Has made four applications for teaching jobs; will accept if the salary is adequate. Liked the advantages of individual research in the university.
	1	Is returning to teaching at first opportunity. Likes teaching better than industrial work.
30–39 years	3	Do not expect to return to teaching because of insufficient salary. Heavy teaching loads were cited as cutting down research time.
	2	Will not return to teaching. Curriculum lags 5 to 10 years behind industry.
	2	Undecided. Salary governing factor. Resent Ph.D. "caste" system.
Over 40	2	Will not return because of insufficient salary. One preferred the personal freedom of industry.
	1	Undecided. Salary governing factor.
	1	Returning. Desires to help in bringing engineering curricula up-to-date.

A number of important conclusions may be drawn from the results of these inquiries:

First, a disconcertingly large proportion of the former college teachers especially among the younger men, plan not to return to teaching.

It is probable that the groups canvassed include a high proportion of the abler young men having good academic preparation, initiative, and originality. It is also probable that they were actuated by a variety of motives in seeking, or accepting, industrial or scientific research positions in time of war: the desire to be of immediate service in developing weapons; uncertainity as to the status of college positions in war time; realization of an intention to leave teaching previously formed; the desire to seize the opportunity to secure practical experience; higher salary; and others. And it is also possible that some of the men would have left college teaching in any event since they may not have been as well adapted to it as to other activities. The fact remains, in spite of these qualifications, however, that too large a proportion of able young men have been lost to the teaching profession.

Second, as would have been anticipated, the higher salaries paid by industry and by scientific research laboratories have been one of the chief reasons which has prompted the decision not to return to teaching.

This basic factor in the entire college teaching profession is, in our opinion, one of greatest importance. Until this condition is ameliorated, there are bound to be less effective faculties than the importance of higher education in a democratic society demands.

Third, it is very disconcerting to note the number of instances in which the greater challenge to the man's ability, the greater rewards offered for it, and the more advantageous conditions of working in non-collegiate environment have influenced decisions not to return to teaching.

In the authors' observation, the failure of many teaching positions adequately to challenge able young men's abilities or to provide conditions under which they may develop themselves for greater responsibilities is a most serious criticism of prevailing conditions in a large sector of education in science and engineering. Higher salaries without incentives for constructive effort beyond satisfaction of routine classroom requirements will probably not go far toward developing outstanding faculties and research staffs.

The evidence here presented and its discussion are not new, but they are closely related to problems of faculty rehabilitation which are extremely acute at present. Demands on the services of the colleges and universities is far beyond estimates. And this demand seems destined to continue even after the early post-war peak. There is a pronounced shift of students toward science and engineering. War developments have so greatly accelerated scientific discoveries and their application that the need for scientists and engineers will doubtless remain permanently above pre-war levels. At the same time, we are entering the post-war era of educational demand and industrial need with faculties seriously in need of rehabilitation. In the authors' institution the engineering faculty is still about 12 per cent below normal in numbers.

Furthermore, institutions are deprived of the usual sources of recruitment of promising young men just at the time when they are most needed in

order to infuse new blood into faculty groups. The situation portrayed earlier in which it is clear that a disconcertingly large fraction of the abler young teachers will not return to teaching is an important phase of the problem. Faculty groups now have a seriously unbalanced age distribution. This still further aggravates budgetary problems. In sum, the seriousness of the faculty problem can scarcely be overstated.

Where can we look to find solutions to this problem? In its broader aspects the solution must be found ultimately in a changed attitude of the American public toward higher education in general and to education for the professions in particular. Either the concept of the number of persons who should pursue higher education must change to smaller proportions or much more adequate financial support must be provided with the purpose of maintaining faculties of adequate numbers and qualifications. That the first of these alternatives will come to pass is scarcely conceivable in view of our American philosophy in relation to education. It is of most vital importance, therefore, that the second alternative be faced squarely on a nation-wide basis.

Second, and more immediately under our control, means must be found to challenge the initiative and capacity of our abler young teachers through good administrative leadership, opportunities for research and other original work, and through adequate and prompt recognition of achievement.

There are other aspects of the matter, however, than those just mentioned. The immediate question is how can we find quickly sufficient reasonably well qualified men to meet the present emergency. There seem to be two chief sources in sight; government (including the armed services and government research laboratories) and industry. If these two groups sense their own needs—both immediate and long range—accurately, they should realize that their own interests must prompt them to facilitate the return of former teachers to college work and to aid colleges to recruit teachers from the ranks of their younger engineers and scientists. As quickly as possible, too, veterans returning as upperclassmen should be prepared for teaching and college research positions. Means should be sought to provide adequate compensation and opportunity for advancement in order to attract them to academic positions.

In all of this, one thing is imperatively necessary if the quality of engineering education is to be preserved and enhanced: in spite of all the difficulties in sight great discrimination must be exercised in choosing every new teacher added to our faculties.

Discussion of "Cooperative Engineering Education for the Teacher Industry's Opportunity."

Your article which appeared in the November issue of THE JOURNAL OF ENGINEERING EDUCATION prompts me to write you a congratulatory note. The essence of your well written discussion hinges about the seemingly important, haughty attitude which teachers often develop *unless* they are tempered by industry. After one has been in industry for ten or more years and he goes to the teaching profession what a shock he gets to note the narrow views and lack of practical knowledge which teachers of engineering often possess. If only the spirit of cooperation would prevail among teachers as it does among engineers in industry!

I think, too, that prospective teachers should have at least six years of industrial experience before they begin. A cooperative graduate program offers the best preparation to my belief. A plan with industry as you propose offers a means whereby teachers can keep abreast of commercial developments. The whole difficulty, of course, lies in the willingness of industry to accept a loss in this teacher training program. The results would come in obtaining better students by industry to overcome the initial loss. A teacher could not hope to repay a company for this training in the short span of a summer's vacation period. But if continued over a period of years the tide might be turned.

The Company with whom I am associated is organizing a cooperative scheme with engineering schools for the development of students of the undergraduate as well as the graduate level. It is realized that this contact with industry answers the problems and it offers incentive to the student. Applications of theory in industry, contact with practising engineers, opportunity to see how things are done and development of a cooperative spirit appeal to the student. He realizes that industry plans for replacements in key positions. Each man has an understudy, no one is irreplaceable. A teacher training program could be carried out similarly. Colleges and Universities should grant leaves of absences to those who have not been seasoned by industry recently. It can be done to the mutual benefit of all.

I wish that more directors of engineering departments in schools would be imbued with your ideas.

M. L. MANNING,
Chief Engineer,
Kuhlman Electric Co.,
Bay City, Michigan

Training Within Industry

Training Within Industry, whose five-year existence makes it one of the oldest wartime government agencies, has issued a narrative account of its work with more than 16,000 war plants and services which resulted in the awarding of more than 1,750,000 certificates to supervisors. The TWI report tells the story of how the organization was set up, how its programs were developed and operated, how the plant managers had to be sold on using the techniques, the mistakes that were made and the improvements that evolved, the results that came about, in a 300-page account of what TWI itself learned about in-plant training as a production tool.

It attempts to give, in impersonal form, a frank, factual and human account of the narrative story of the days in which it contributed to the production of war goods and services through management techniques for showing supervisors how to get skilled work from inexperienced people quickly, and labored incessantly to convince management that the training of men is a major function of management. The account is drawn from operating records which are now in the National Archives. It is available through the U. S. Superintendent of Documents at a cost of 50 cents a copy or 37½ cents for orders of 100 or more copies.

TWI's history covers the period from the Fall of France in 1940 to V-J Day. The same leaders directed its work throughout—C. R. Dooley, Director; Walter Dietz, the Associate Director; and two Assistant Directors M. J. Kane and William Conover. The TWI organization was made up of industrial people, many of whom remained on their companies' payrolls. Its staff of 400 people were located in 21 district offices throughout the United States, and one district office in the Hawaiian Islands.

The TWI organization was started under first the National Defense Advisory Commission and later transferred to the Office of Production Management, then to the War Production Board, then to the Federal Security Agency, and in 1942 to the War Manpower Commission. TWI's service to war plants concluded after V-J Day at the same time that WMC was abolished. In all of its various offices throughout the country TWI used the part-time assistance of many company men in the development and extension of its supervisory training programs—Job Instruction, Job Methods, Job Relations, and in its program for plant training directors. Labor advisers assisted in the adaptation of the Union Job Relations program to labor unions.

TWI became widely known for its 4-step method (printed on pocket cards) which formed the backbone of the programs. Each was developed along a common pattern—first, demonstration of the particular 4-step method, then individual practice in use of the method by each member on one of his own problems.

Results of the TWI programs were

concrete and measurable—they ranged from a monthly saving of $300 in pork trimmings at a small packing plant to the spectacular ones like the saving of three-quarters of a million dollars on the construction of one ship. These results took place in huge new plants built specially for the war and manned largely by ribbon-clerks and gas station attendants, in old established plants where capacity and output had to be multiplied, in small specialized plants, and even in hospitals in crowded war centers. The TWI programs were adopted by the Army Service Forces, by several government agencies, by the governments of Great Britain and Canada. They have spread to many other countries by the subsidiaries of American companies.

Training Within Industry Foundation

The Training Within Industry Foundation has been incorporated in New Jersey as a non-profit organization which will carry on the research work of the war-time, government T.W.I. service, whose directors are now the trustees of the Foundation.

C. R. Dooley, who was loaned to the government from 1940 to 1945 by the Socony Vacuum Oil Company of which he was industrial relations manage, is the director of the Foundation and heads the staff at its headquarters in Summit, New Jersey. Walter Dietz, borrowed during war-time from the position of personnel relations manager of the Western Electric Company, is assistant director of the new group, the same position he held in the government T.W.I. service. William Conover and M. J. Kane, the other trustees, were assistant directors of T.W.I. during war-time. Lawrence J. MacGregor, president of the Summit Trust Company, is the treasurer.

The Foundation is being supported by member companies which have made extensive use of the T.W.I. programs of Job Instruction, Job Methods, Job Relations, and Program Development. The first research of the Foundation is dealing with the use of these means of supervisory development on problems of conversion, absorption of returning veterans, and other 1946 industrial problems.

For further information, write or phone the Training Within Industry Foundation, Room 515, Bassett Building, 382 Springfield Avenue, Summit, New Jersey.

THE T-SQUARE PAGE

Officers
JUSTUS RISING
J. L. HILL
I. L. HILL
F. A. HEACOCK
G. M. PHELPS

DEVOTED TO THE INTERESTS
OF ENGINEERING DRAWING

H. E. GRANT, *Editor*
The University of Wisconsin in Milwaukee

Officers
F. M. PORTER
E. C. WILLEY
W. E. STREET
J. N. ARNOLD
J. M. WOOD
H. E. GRANT

FIRST ANGLE PROJECTION

Orthographic projection is the international language of the engineering field. Thus it behooves us as teachers to consider the proposition of teaching our engineering students to read the language regardless of where the drawing on which it is used originated. Though the individual views are the same in all countries, the shifting of the views may cause the American engineer considerable difficulty if he is not aware of the fact. The minor obstacle of reading the notes written in a native tongue is easily surmounted with the aid of a foreign language dictionary.

First angle projection is used by almost every industrial concern in the world except those in the United States and Canada and about one-half of the concerns in England. Although we in the United States use third angle projection exclusively, there are many reasons why first angle projection, as well as third angle projection should be taught in this country. The primary reasons are:

1. Most large and some small industrial concerns regularly receive foreign drawings in connection with their international dealings.
2. Progressive engineers read foreign technical literature.
3. Our drawings used in advertising literature, instruction books, etc., need to be changed to first angle projection for use in foreign countries.
4. Some engineering graduates go to foreign countries as employees of American or foreign concerns.
5. Foreign students enrolled in U. S. engineering schools should learn here how to read the drawings of their own countries.

The wide international use of first angle projection, as well as the reasons enumerated above, commands the American drawing teachers to give serious thought to making it a part of their courses.

STUDENT MATERIAL AND COURSE OUTLINE DISPLAY

There will be a Summer School for Engineering Drawing Teachers at Washington University, St. Louis, Missouri, June 18–28, 1946.

All colleges and universities are requested to bring or send to the Drawing Teachers Summer School, bound copies of the work done in their school, in all drawing courses during the current or immediate past few years. These firmly bound folders should preferably include course outlines, student work of all problem material and examinations. The student work need not be selected for excellence, but merely to show a cross section of the average work and possibly may be from different students. All of your courses in drawing and descriptive geometry should be exhibited so that we may have a complete and large display. All sheets should be bound together in order of presentation so that sequence may be observed by those viewing them. They should be plainly marked on the outside cover as to School, Course, Credit Hours, and Clock Hours per Quarter or Semester. These will be displayed on tables and not mounted on walls because of lack of space.

Bring or send all display material to:
Professor R. W. Bockhorst
Department of Applied Mathematics
Washington University
St. Louis 5, Missouri

At the end of the Summer School this material is to be picked up by the various school representatives or returned by express collect to the schools who have not taken up their display.

The object of holding such a display is to acquaint the members of the drawing division with the work that is being done throughout the country.

IT IS ENTIRELY INSTRUCTIVE AND NOT COMPETITIVE.

Committee on Student Display:
F. M. PORTER
W. E. STREET
J. M. RUSS
R. W. BOCKHORST
R. S. PAFFENBARGER, *Chairman*

Engineers' Council for Professional Development

At the annual meeting of Engineers' Council for Professional Development, October 19–20, 1945, the following resolution was unanimously adopted, and sent to the Honorable John W. Snyder, Director of War Mobilization and Reconversion:

WHEREAS national security and public welfare are dependent upon and vitally affected by the quality of scientific, engineering and technological research, both fundamental and applied;

WHEREAS fundamental and applied research are entirely dependent upon an ample supply of trained and experienced manpower;

WHEREAS the ranks of scientists and engineers have been seriously depleted since 1941 by the requirements of military service;

WHEREAS the normal flow of students into the colleges and the engineering, technical, and graduate schools has almost completely ceased during the period from 1941 to 1945;

WHEREAS the alarming deficit in highly trained technical personnel will be further increased if Selective Service is continued without full recognition of the fact that technical personnel is as vital to national security and welfare as military personnel;

WHEREAS the acute shortage of scientific and engineering personnel in the colleges, in government agencies and in industry must be immediately alleviated in the national interest;

WHEREAS full cooperation of the legislative and executive branches of the Federal Government is essential, not only in the implemention of this emergency program which is designed to correct the deficit (now estimated at approximately 150,000) of scientific and technical students, but also in assuring a future supply of trained manpower, adequate in numbers and in skill to meet the involved problems of national reconversion, progress, welfare, and security.

THEREFORE BE IT RESOLVED

(1) that deferment procedures for those in scientific and engineering training at graduate and undergraduate levels and also for those in scientific and engineering occupations in industry and in professional pursuits, including teaching, be reestablished.

(2) that those whose engineering education was interrupted by entrance into the Service be given the option of discharge to civilian status to complete their professional engineering training.

(3) that every effort be made to release from the Service those men who have completed their professional engineering training in order that they may be immediately available to lessen the critical shortage existing in the engineering profession.

(4) that to enable men to complete their engineering training deferment be granted to those students who have not yet finished preparatory school but have been accepted by an accredited engineering college.

THEREFORE BE IT FURTHER RESOLVED that the imperative and immediate need of replenishing scientific and engineer

ing man power be called to the attention of the President and the Congress. BE IT FURTHER RESOLVED that the President be asked to take prompt steps through the Selective Service procedure to insure a flow of scientific and engineering personnel through the colleges and the engineering, technical and graduate schools adequate to national security and the public welfare.

The Engineers' Council for Professional Development represents seven participating engineering societies in the United States, as follows:

American Society of Civil Engineers	—21,100 members
American Institute of Mining and Metallurgical Engineers	—12,600 members
The American Society of Mechanical Engineers	—20,060 members
American Institute of Electrical Engineers	—24,526 members
Society for the Promotion of Engineering Education	— 3,922 members and 162 institutional members
American Institute of Chemical Engineers	— 5,788 members
National Council of State Boards of Engineering Examiners	— 50 member boards reporting over 78,000 registered engineers

We at this time present this resolution to you in order that the action of the ECPD in this important subject, which is of greatest interest, may serve you at this most important moment.

Very truly your
EVERETT S. LEE,
Chairman

The following reply has been received:

Dear Mr. Lee:

Mr. Snyder has referred to me your letter of January 18, relating to deferment and demobilization policies as they affect scientific and engineering personnel.

At the request of this office, the Selectice Service System has agreed to give special consideration to the deferment of scientists and engineers. A copy of the Selective Service regulation establishing this policy is attached.

Selective release of highly qualified personnel essential for reconversion activities is now under discussion with the War and Navy Departments.

We appreciate receiving a copy of your recent resolution, and assure you that we are keenly aware of the necessity of expanding the group of highly qualified technical personnel whose work is so important to reconversion and to research in the physical sciences.

Very truly yours
S. J. DONALD KINGSLEY,
Director for Manpower Office of War Mobilization and Reconversion, Washington, D. C.

Necrology

George Frederick Eckhard, Dean of the College of Engineering at the University of Vermont, died at his home in Burlington on December 28, 1945, after an illness of several months. He was born on November 21, 1878, in Waverly, Iowa, the son of George and Katherine Eckhard. He was educated in the public schools of Cedar Falls, Iowa, attended the Iowa State Teachers College, from which he received the degree Master of Didactics in 1900, and received from the State University of Iowa the degree B.S. in Civil Engineering in 1905 and the professional degree of Civil Engineer in 1910.

Dean Eckhard was a man of broad professional experience which made him eminently qualified as an educator and administrator. He was employed by the Cuba Eastern Railway in 1905, from 1907 to 1909 was professor of civil engineering at the New Mexico School of Mines and during the same period held the position of City Engineer of Socorro, New Mexico, and was United States Mineral Surveyor for the State. From 1909 to 1912 Dean Eckhard was professor of civil engineering at James Millikin University; and from 1912 to 1915, at the Pennsylvania State College. He joined the faculty of the University of Vermont as professor of structural engineering in 1915 and became Dean of the College of Engineering in 1932. Under his direction and largely through his efforts the facilities of the College of Engineering of the University were expanded to their present level.

Dean Eckhard was very active in civic and state affairs, having served for twenty years as street commissioner of the City of Burlington; and as president of the Vermont Society of Engineers in 1932. He was active in sponsoring the law for the licensing of professional engineers in the State of Vermont and was chairman of the Board of Registration for Professional Engineers at the time of his death. He was a member of the College Street Congregational Church of Burlington and active in church affairs.

His professional affiliations included the Society of the Sigma Xi, American Society of Civil Engineers, Society for the Promotion of Engineering Education of which he was a member of the Council for three years, Vermont Society of Engineers, and the American Academy for the Advancement of Science.

College Notes

Dr. Ben H. Parker, vice-president of the Frontier Refining Company for the past two years and prominent in mining and petroleum industry circles in Colorado and the West, has been named president of the **Colorado School of Mines** to succeed Dr. M. F. Coolbaugh, whose retirement was announced in October. Dr. Parker assumed his new duties January 1.

He was born in Oklahoma City November 3, 1902. He graduated from the Colorado School of Mines with the degree of engineer of mines in 1924 and received the doctor of science degree from that institution in 1934.

He was a member of the faculty as associate professor of geological engineering from 1933 to 1943 except for the school year 1939–40, when he was on leave of absence to serve as assistant chief geologist for the Argentine government oil fields, with headquarters in Buenos Aires. While a member of the faculty at the School of Mines, he was also institutional representative for the school for the Engineering, Science and Management War Training program and was armed forces representative during the Army Student Training program.

From 1924 to 1931 he was actively engaged as petroleum geologist in Oklahoma, New Mexico, Utah, Wyoming, Kansas, South Dakota, Texas and Colorado for the Marland Oil Company, the Gulf Oil Corporation and E. W. Marland, Inc. He has also been part owner and operator of mines in Clear Creek, Golpin and Summit counties, Colorado, and a member of the firm Parker and Boyd, consulting mining engineers, as well as an officer and director in several mining and petroleum production organizations.

Iowa State College.—Charles M. Dodd, who for the past three and a half years has been Acting Engineering Personnel Officer, returned to his regular position as head of the Ceramic Engineering Department on November first of last year. In addition to his duties as Engineering Personnel Officer, Professor Dodd served as Armed Services Representative and Educational Coordinator of the Navy V-12 program at Iowa State College.

Andrew L. Johnson has been appointed as Research Associate Professor of Ceramic Engineering and assumed his duties at Iowa State College on January second. Dr. Johnson was formerly with the Massachusets Institute of Technology as assistant professor of ceramics.

Harry J. Beckemeyer, who has been on leave with the Navy in the South Pacific for the past twenty-one months, has returned to Iowa State College to resume his duties as Instructor in the Department of Ceramic Engineering.

University of Michigan.—A new four-year curriculum in Mechanical and Industrial Engineering will be offered by the College of Engineering, effective with the start of the Spring Term on March 4.

The new curriculum, which replaces

a five-year program, will lead to a degree of Bachelor of Science in Engineering (Industrial-Mechanical). The five-year program was based on the requirement of 140 hours of undergraduate work for the degree of Bachelor of Science in Engineering (mechanical engineering) and 24 hours of graduate work for the degree of Master of Science in Industrial Engineering.

No change has been made in the basic requirements for the new four-year curriculum and 140 hours of undergraduate work will be required for the degree. It is felt that a student who wishes to take further work in the industrial field will find no difficulty in selecting courses to suit his requirements.

Michigan College of Mining and Technology.—The reconversion period finds the college already much expanded in activities and physical plant, planning additional expansion, and on the way back toward its pre-war enrollment of approximately a thousand students.

Registration this past fall term was 42 women and 337 men, including about 150 war veterans.

The general engineering degree has been dropped, and new degrees have been authorized in physics and in engineering physics. These changes mean that the college is offering undergraduate degrees in nine branches of engineering and in four branches of science. The most popular option under General Science is that in medical technology. Students take three years on campus, and the fourth year at an accredited hospital or Michigan State Health Department laboratory where they serve what amounts to a practical apprenticeship under certified, professional medical technologists.

The department of mining engineering, civil engineering, and economics has been divided into three departments. The new head of the mining engineering department is Prof. J. Murray Riddell, an alumnus of the college who has had extensive mining experience as operator, executive, and consultant and in research. The new civil engineering head is Prof. (formerly Assoc. Prof.) W. C. Polkinghorne, member of the staff since 1921, who received his academic training at M.C.M.T. and at Yale University. The economics section has been expanded into the department of engineering administration, under Assoc. Prof. E. J. Townsend, alumnus and member of the faculty since 1931. Engineering administration embraces not only economics but personnel administration, industrial psychology, industrial sociology, and American government and politics.

All departments have examined and revised their curricula. In doing so, many have been able to meet or approach the recommendations of the Society for the Promotion of Engineering Education relative to an increase in the amount of time and attention devoted to the "humanistic-social stem." The establishment of the engineering administration department is in line with this trend. Also relevant is an increase in the number of undergraduate hours to be devoted to speech and writing, and the authorization of an elementary course in Portuguese to complement the offerings in Spanish, French, and German.

Other changes in the undergraduate courses include the offering of refresher work for war veterans and others whose engineering education was interrupted by the war, and of

modernization courses to bring such men and women up to date on the latest developments.

The college has increased its emphasis on graduate work, revised somewhat the sequences of M.S. courses in the various engineering and scientific fields, and tied in its graduate research projects more tightly both with its industrial research and likewise with the numerous investigations which the college pursues as a State agency collaborating with the State Planning Commission and similar bodies.

One aspect of postwar planning is the recent establishment of M.C.M.T. of a Forest Products and Timber Industries Institute. This division conducts research; gathers, interprets, and disseminates information; and also operates a Practical Woods Industries School of thirty-three weeks to train men for semi-technical jobs in the woods and mills. Such men spend three-fifths of their study time in the woods, living at a camp about fifty miles from Houghton. This is one of a number of terminal courses offered by the college for men and women seeking intensive practical training that does not lead to a degree. Among other terminal courses offered or scheduled are drafting, machine drawing and shops, surveying, assaying, chemistry, and business training.

A second major aspect of State planning is a joint research project on improvement of the forest and woods industries, with the Michigan College of Mining and Technology, the University of Michigan, and Michigan State College collaborating. Funds are provided by a State grant.

Faculty members who have recently returned from the armed forces include Assoc. Profs. R. W. Drier, metallurgy, and B. B. Bennett, languages; Messrs. Edward Maki, physical training; Chester Pratt and Thomas Vichich, mathematics; and Franz Schubert, director of music. Assoc. Profs. H. W. Risteen, mechanical engineering, and Jerry Service, physics, are expected to return soon. The former is a captain and the latter a commander in the U.S. N.R. Assoc. Prof. C. G. Stipe, mathematics, is on leave teaching at Shrivenham American University.

Buildings recently added to the plant by construction, purchase, or lease total nine. One is a Special Shops Training building. Four are dormitories housing from twenty to fifty students each. One is a Health Service Center, one a classroom and office building for the departments of forestry and military science, another a cafeteria capable of handling 200 persons at a time, and the largest is the James R. Dee Stadium. This is a winter sports building with a large hockey rink, bleachers for 1,100 spectators, and change and locker rooms. The most extensive asquisition is the Michigan Tech. nine-hole golf course, totaling 55 acres. It has a sizeable, well-appointed clubhouse.

These additions to the physical plant will be further increased soon by a new Central Heating building and a physical Training building, for which funds have been appropriated by the legislature.

The college has increased its emphasis on lyceum as well as industrial lectures and on motion pictures, panel discussions, informational and personal reading, and the like. Part of the program involves closer correlation of student and faculty activities—the S.P.E.E. branch playing a considerable role—and the broadening of the scope of the student advisory program, which is now restricted largely to academic matters.

Physics Column

The Executive Committee of the Physics Division met in New York City February 1–2 at the time of the meeting of the American Physical Society and the American Association of Physics Teachers. Plans were discussed for the annual meeting, which will also be the occasion for the summer meeting of AAPT. The program chairman of AAPT, Paul Kirkpatrick of Stanford University, and your chairman are working on a program which should eclipse anything which has been offered in the joint activity of the two organizations.

Attention of members of the Division is called to the Report of the Committee on Curricula in Engineering Physics, which appears in this issue of THE JOURNAL. The trends indicated in this report merit the attention of administrators of engineering education.

JAMES G. POTTER,
Chairman

CASE SCHOOL OF APPLIED SCIENCE has announced the following new appointments to its faculty to take effect at the start of the new term on March 4, 1946: Oscar Hoffman, Associate Professor of Civil Engineering; F. L. Taft, Assistant Professor in English; John B. Scalzi, Assistant Professor of Structural Engineering; Robert C. Weast, Assistant Professor of Chemistry; Harold K. Crowder, Instructor of Mathematics; W. F. Downey, Instructor in Chemistry and Chemical Engineering; C. J. Kessler, Instructor in Engineering Drawing; Robert L. Maxwell, Instructor in Mechanical Engineering; A. R. Pray, Instructor in Chemistry; David M. Rein, Instructor in English; Robert Strough, Instructor in Physics; William Vaisman, Instructor in Mathematics; David D. Van Horn, Instructor in Physics; William Baldwin, Special Lecturer in Metallurgy; G. P. Kerr, Special Lecturer in Physics.

The Qualities of a Profession—Endless Horizons*

The Engineering Profession

But our principal concern here is the engineering profession, and we inquire, what is the engineering profession; is it a profession at all; and if it is, will it develop into the full stature to which the importance of its work entitles it to aspire?

It is relatively young. The military engineer appeared in the first steps of mechanization of warfare, when forts began to take shape. His counterpart in peaceful affairs was called a civil engineer. With the industrial revolution, and especially with the spread of mechanization from the factory into every walk of life, engineering became exceedingly diversified. Applying science in an economic manner to the needs of mankind is its broad field. Its disciplines are spread over all the sciences as they become thus applied, and embrace also portions of economics, law, and business practice which are integral parts of the process of application. It is somewhat loosely organized as professions go. To a minor extent only, it limits its numbers; but the very strictness of its essential disciplines provides some selection of its neophytes. Until recently it has done very little in an organized fashion to inculcate in its younger members the philosophy of the profession, leaving this largely to those of its individuals who are also members of the teaching profession. That branch which represents the consultant, and others to a degree, has drawn codes; but there is no body of codified principles which is accepted and applied by the profession as a whole. It has no highly distinct language or jargon, for it must continuously work with laymen.

These are, however, incidentals. The important point is this: Does it have a central theme of ministering to the people? Most certainly it serves the public in myriad ways, but are its individual members activated primarily by the professional spirit of dignified and authoritative counsel and guidance?

The Business Profession

In order properly to inquire into this weighty question, we need to digress a moment to consider another large group of the population, the modern men of business who have derived from the ancient traders and merchants. The merchant class has not usually been a professional grouping in the true sense; and engineering, which has derived its philosophy from this source as well as from science, naturally partakes of the heritage of both groups. Business has served the public, of course, but its main theme has been the profit motive, a salutary objective when restricted by law to the use of ethical procedures in its pursuit, but not a professional objective.

One of the most encouraging signs of the times is the gradual emergence in our day of the truly professional

*Reprinted, with permission, from "Endless Horizons," a book by Vannevar Bush, published by Public Affairs Press of Washington, D. C., pages 137–145.

man of business. Scattered, not organized, with no sign of professional trappings, they are nonetheless possessed of a high mission, which needs only formulation and recognition in order that they may constitute a new and strong profession. This is occurring for one reason because of a gradual change in corporate form. The owner-manager was activated by the profit motive, and no amount of paternalism could wholly alter his position in the social theme. Even with corporations, the ownership of which is widely scattered, the manager is ordinarily controlled by and primarily responsible to a few powerful owners, so that he in essence still represents the interest of the owners in his relations with the three bodies with which he deals: the government, the employees, and the consuming public. It is his difficult task to reap for the owners' benefit the fruits of his industrial operation, while maintaining at least tolerance on the part of the other bodies. But there are some corporations in which ownership is so diffused that the management becomes in effect a self-perpetuating entity, partaking therefore of the nature of a trusteeship, with equally weighed obligations and responsibilities to all four bodies: owners, employees, government, and consumers. Among such managing groups will be found individuals who have the professional philosophy in high degree, conducting their affairs for the just and equitable benefit of all four groups concerned, maintaining the health and progress of their institutions as potent agencies for ministration to the needs of the people. They find common ground with the trustees of great foundations, of hospitals, and all non-profit organizations devoted to the public welfare. They find common ground also with many of those who make a career of the business of government. Their ranks are recruited by many in the ordinary walks of business who have seen a light and envisioned a function of life which is higher in its satisfactions than the struggle of any body against any other; namely, a struggle with all bodies to preserve an ideal. Out of this trend, as competition for industrial existence becomes tempered, should emerge a new profession with its own traditions and beliefs, which is capable of managing prosperity so that it will be conducive to the health of a nation; and there is grave question whether this objective can be attained in any other way. I wish there were a special order of knighthood in this country to honor and unite those who are now blazing the difficult path and developing the novel philosophy of this new profession.

Engineering, however, derived jointly from the quiet cloisters of science and from the turmoil and strife of aggressive business, and it is no wonder, therefore, that it should wobble a bit as it seeks to evolve its own professional philosophy. Just as it is not reasonable to expect the young neophyte to grasp at once the idealism of his calling, so it is perhaps not reasonable to expect a profession which is so young and which has grown so fast to have found itself in this regard.

Entrance into a Profession

The period of initiation into any profession should extend into maturity. Only when members reached the full bloom of manhood did the ancient orders entrust the mysteries to their care. The young neophyte served his apprenticeship under constant tutelage and close guidance by mature minds, and this we still find in every profes-

sion. As apprentice, as employee, he is called upon to prove himself before he enters into that relationship where his opinions are controlling in his special field, and some there are who never emerge from close control and the mere exercise of technical proficiency. In the engineering profession this emergence usually is circumscribed by the fact that most engineers operate as members of industrial organizations of one sort or another, and the fact that they serve their apprenticeship in this same sort of organization and come to devote their entire efforts to its affairs, rather than to enter them after professional recognition elsewhere, as is usually the case with medical or legal individuals. This, however, merely emphasizes the need for better supervision of the neophytes by the members of the engineering profession who have arrived. It is not enough to leave their training to the industrial organizations of which they are junior members. Inculcation of the principles of the profession can come only from those who themselves have attained to a full grasp of its proper function in society, who have arrived at a balanced judgment as to its responsibility to the several groupings of which society is composed, and who have a professional interest in the young men who are destined to succeed them in the profession. Every profession should have its secrets and its mysteries spread before the world that all may read, but truly grasped only by those who have lived the professional life; and these should be transmitted to the neophytes with due care, with reverence for their inherent worth, and in due time. Ritual and symbolism, secrecy and circumspection, were the ancient paraphernalia which insured a proper seriousness in youth in order that the importation might be impressive. These have not wholly disappeared from modern professions. Admission to the bar, the use of the title of doctor, and similar customs and usages have profound effect in producing a professional consciousness. The engineering profession is wholly without these aids, and its task of inducting its neophytes into the true professional atmosphere is thus rendered doubly difficult.

But does it matter at all? Are the things that engineers do so vital that they must needs be approached in the professional spirit? Most certainly it matters. And most certainly the task is a professional one. The impact of science is making a new world, and the engineer is in the forefront of the remaking. He lights the way in a very literal sense. He brings peoples close together for better or worse, by facile communication and rapid transportation. He guards the food supply, and replaces the hopelessness of Malthus with an embarrassing plenty. He shortens the hours of labor, and fills the consequent leisure with distractions. He temporarily disrupts the techniques of whole industries, and thus alters the life habits of many people, in maintaining a continually rising standard of living. He bores through the earth and under the sea, and flies above the clouds. He builds great cities, and builds also the means whereby they may be destroyed. Certainly there was never a profession that more truly needed the professional spirit, if the welfare of man is to be preserved.

Expression of Professional Spirit

There is no lack of signs of a rising consciousness in this regard. The profession is most positively vocal. There is a vigorous new organization, link-

ing several large groups, devoting itself to the improvement of the education of the young engineer, and the instillation of high principles during his early career. Engineering literature is full of discussions of the duties and responsibilities of the profession, and out of this may crystallize some day a code, a set of principles of conduct, a guide drawn solely with the object of advancing the public weal, which will become accepted by engineers everywhere, whether in government employ, private practice, or industrial organization. Having to some extent, at least, consolidated their techniques, engineers are certainly giving thought and voice to their position in society, and to their responsibility for the use of the great works which they create.

The focus of this whole affair is the American Engineering Council. More than any other group it represents the engineering profession as a whole, in its relationships with government, other professions, and the public. Here, more than in any other organization, reside the external as contrasted with the internal relationships of the profession. It was founded by men who considered its functions in terms of a high idealism. It is now going through a strenuous period of self-examination. To this every individual can contribute only one set of thoughts to be merged with all of those which seethe, and interact, out of which will come in due time that concensus which will form the opinions, traditions, codes, and consciousness which will mold the engineering profession. It will come unless the Council fails; for if it fails, and if its place is not taken by a more rugged successor, there will be no unitary engineering profession at all. In the spirit of adding my few thoughts to those of the eminent men who are directing the Council I have previously offered comments, and I now comment again with the expectation that I will be disagreed with and answered, with the wish to add my mite to the consummation.

I find it a vigorous and rapidly evolving body. I consider it to be utterly inadequately supported by the profession as a whole, in comparison with the central bodies of sister professions, and with a serious problem as to how adequate support can be drawn for the great task that lies ahead of it. I find it partaking of the great American tendency toward overcomplication, and inclined to attempt things which seem to me personally to be off the main beat. I find to my great joy that it is gradually becoming known and recognized; and I trust this is just a beginning. I find it guided by some of the best minds in the profession as its officers, who are giving valuable time to its cause; and I hence cannot fail to be optimistic as to its future.

To me, however, there is just one point on which I wish to focus attention. I find it struggling with its own philosophy. I find, in fact, that it hesitates as it formulates its idealism; that it has not yet placed its foot unequivocally and irrevocably upon the path that leads to complete devotion to the public welfare. I find that it has not yet enunciated its belief that the great mission of the engineer lies in intelligent, aggressive, devoted ministration to the people. This I urge with all the emphasis I can command.

Necessity for a Central Organization

I do not seek to conjure away practical difficulties by ignoring them. I know full well what restricted budgets mean. The argument that the support

of the membership can be obtained only if they can see a direct and personal benefit from their contributions has a familiar ring. I recognize that it is entirely proper for professional men to join in an insistence upon a reasonable and proper recognition of their services to society. Yet if there is no central organization which has as its creed the best service of the profession to the society of which it forms a part, then there will be in the end no engineering profession. Professional status rests in perpetuity, not on transient law, not on the cruder machinations of the ancient guilds, not on exclusive control of those having a specialized and necessary knowledge; but upon the respect and fundamental support of the people who are served, who only in the long run can insist upon the maintenance of prerogatives, and confer honor, recognition, and special privileges in society upon the members of a profession.

Will engineers support such a program? Will they contribute directly or through their specialized societies to the development of this ideal, and its exemplification in Council projects aimed at rendering real some aspect of the profession's contribution to public welfare? Will they make possible great forums for the crystallization of engineering opinion on public questions involving engineering, not to attain an impossible unanimity or produce high-sounding resolutions, but so that all aspects of controversial matters may be aired in order that people may know what engineers think? Will engineers go along heartily in developing a professional consciousness, a code of action, a philosophy which implements a desire to be a truly professional group, oriented primarily toward the advancement of the public health, safety, comfort, and progress? Will they accept as the central theme the engineers' ministration to society, without fear of any class, and without prejudice toward or away from any special social interests or causes?

If they will not, then there is no truly professional spirit to build upon. We may as well resign ourselves to a gradual absorption as controlled employees, and to the disappearance of our independence. We may as well conclude that we are merely one more group of the population, trained with a special skill, maintaining our economic status by a continuing struggle against the interests of other groups, forced in this direction and that by the conflict between the great forces of a civilized community, with no higher ideals than to serve as directed, and with no greater satisfaction than the securing of an adequate income as one member in the struggle for the profits of an industrial age.

But I know the minds of too many engineers to be thus pessimistic. I recognize the distinguished careers of a generation of men who have practiced in the profession to its credit and honor. Though the task be difficult, on account of the nature of many of our relationships to society, nevertheless traditions are being formed, the consciousness of the membership is becoming aroused, and I confidently expect the profession of engineering to develop in a manner of which we can be justifiably proud.

And to those in the ranks who may not have yet seen the light, I would preach the doctrine, without pulling any punches, without mincing any words, that the path of professional attainment lies open before them, that it is a thorny path that is easily lost sight of among the rocks and rubbish, that it can be adhered to only by sacri-

fice and by support of those who lead the way, that it is a long path which leads down into the valley into which the sun does not shine, but that it leads at last to the heights—to the heights of true professional attainment, where honor and individual recognition b fellows is the real reward, and ther the watchword is that old, old them which has never lost its power, an which may yet save a sorry worl simple ministration to the people.